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Physical and Chemical Data Series from Clearwater, Lohi, Middle and Hannah Lakes near Sudbury, Ontario

Long-term Responses to Liming, and Natural Recovery from Historical Acidification and Metal Contamination

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Physical and chemical data series from Clearwater, Lohi, Middle and Hannah lakes near Sudbury, Ontario: long-term responses to liming, and natural recovery from historical acidification and metal contamination

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Executive Summary

1. Middle, Hannah, Lohi and Clearwater Lakes were four Sudbury lakes included in the Ontario Ministry of Environment's 1973 – 1978 Sudbury Environmental Study (SES). In 1973, these four lakes were very acidic (pH levels 4.2 – 4.3), and contaminated with several, so-called heavy metals, especially Cu and Ni. During the SES, whole-lake base and nutrient addition experiments were conducted in Middle, Hannah and Lohi Lakes. These experiments were designed to help identify the causes of environmental damage and to assess the possibilities for eventual recovery. Since 1979, the four lakes have been sampled on roughly a monthly basis during the ice-free season in order to determine the possibility, pace and extent of recovery from severe historical acid and metal contamination.
2. During the 29 years of monitoring, there have been significant changes in local meteorological conditions in the Sudbury area. There have been no significant long-term trends in hours of sunshine or annual precipitation, but air temperatures and wind speeds have changed. Mean annual temperatures increased by 1 °C, because of a 2 °C increase in winter temperature. More significantly, in terms of its probable impacts on local lakes, mean annual, ice-free and ice-cover season wind speeds declined by about 30% over the three decades, most of the decline occurring in the first half of the record. Reduced early-season wind speeds inevitably have led to earlier stratification in the study lakes, and cooler hypolimnia at the onset of stratification.
3. Over the 29 years of monitoring, the water quality of Clearwater Lake, the non-manipulated lake, has improved dramatically. The chemistry of the remaining three lakes was dramatically altered by additions of base, and less so by additions of phosphorus. Since the termination of these whole-lake experiments, the water quality of the lakes has continued to improve. In the case of Middle and Hannah Lakes this is in part because of regional land management efforts during which base was added to their watersheds. The four lakes now have stable circum-neutral pH, substantial alkalinity, and greatly reduced metal concentrations.

4. There have been substantial changes in optical properties in Clearwater, Lohi, and Middle Lakes over time. Concentrations of dissolved organic carbon, and, more recently, chlorophyll, have increased, and this has led to long-term decreases in water transparency. As water transparency was unusually high in 1973, this reduction in clarity should be interpreted as limnological recovery.
5. Because of reductions in wind speeds and water transparency there has been substantial recovery of thermal regimes in Clearwater, Lohi and Middle Lakes. In particular, mixing zones are now shallower, hypolimnia are cooler, and volume-weighted whole-lake temperatures are lower. Coldwater profundal habitat has been created in Clearwater and Lohi Lakes where only cool waters formerly existed. Cool water profundal habitat has been created in Hannah and Middle Lakes, where all waters were once warm.
6. There have been substantial changes in nitrogen concentrations and speciation over the time series. In Middle and Hannah lakes, total nitrogen levels were very high in 1973, attributable mainly to ~0.5 $mg.L^{-1}$ of NO_3- N. By 2001, total-N levels had dropped by 2-3 fold, because of 20-50-fold reductions in NO_3 concentrations. In Clearwater and Lohi Lakes, total N concentrations were similar at ~ 300 $\mu g.L^{-1}$ at the start and end of the study, but the organic fraction of the total had increased from roughly 10 to 80%. These changes in nitrogen speciation and concentrations are another sign of recovery in the lakes.
7. De-icing operations, particularly on the Highway 17 bypass, have apparently altered the ionic composition of the lakes, dramatically increasing both Na and Cl concentrations, particularly in Middle and Hannah lakes. These changes in ionic composition may reduce the usefulness of the data sets for regional recovery extrapolations.

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1. Introduction

Dry and wet atmospheric deposition of sulphur has had profound impacts on the chemistry and physics of thousands of soft-water lakes in eastern North America and Europe over the last half century. In locations where deposition rates were relatively modest, <10 kg/ha/yr of sea-salt corrected S deposition, they were generally balanced by primary weathering, and there were no long term reductions in lake or stream alkalinity (Jeffries et al., 2003). Rather, base cation concentrations - Na, K, Mg, but especially Ca – of streams and lakes increased, balancing the increase in sulphate. Where S deposition rates exceeded weathering rates over the long-term, stream alkalinity fell, and rates of acid supply to lakes increased. When total acid inputs to lakes from inflows and from the atmosphere exceeded the rates of internal alkalinity generation, then lake alkalinity, and eventually, lake pH, fell. The principle internal sources of alkalinity generation in lakes are assimilatory or dissimilatory nitrate and sulphate reduction, sediment ion exchange (Schindler et al.1986), and biological or photochemical dissolved organic carbon oxidation (Kopacek et al. 2002). As paleoecological investigations confirmed that thousands of lakes in North America did acidify (eg. Cumming et al. 1992), it is clear that acid supply rates to many lakes exceeded internal alkalinity generation capacity, eg. (Neary and Dillon 1988).

The chemistry of lakes changed in many ways as pH fell. In the short term, base cation concentrations were elevated from pre-acidification levels in response to increased rates of weathering of catchment materials. When acidification became severe, dissimilatory nitrate reduction ceased, and nitrate concentrations rose. Concentrations of dissolved organic nitrogen also fell (Rudd et al. 1988; Yan and Miller1982), and a source of alkalinity production (nitrate reduction) disappeared. At pH <5, concentrations of several metals dramatically increased. Such increases

were observed for Mn, Fe, Cd, Zn, and Pb (Almer et al. 1974; LaZerte 1986) but they were particularly dramatic for Al (Cronan and Schofield 1979). Indeed Al levels rose to presumptively toxic concentrations for fish in many acidified lakes (Driscoll et al. 1980). At pH levels <5, there were dramatic reductions in concentrations of chromophoric dissolved organic carbon (DOC), the principal light attenuator in Canadian Shield lakes (Fee et al. 1996; Pérez-Fuentetaja et al. 1999). Levels fell in part in response to precipitation and flocculation with metals (Helmer et al. 1990), but more likely in response to increased rates of photooxidation by UV radiation under acidic conditions (Gennings et al 2001). It is possible that there were also modest reductions in total phosphorus (TP) concentrations, particularly near pH 5, although the existence of such changes remains contentious. Certainly if TP levels were reduced there was little evidence of reductions in algal biomass, or in total areal photosynthesis rates (Dillon et al. 1984). In summary, in comparison with non-acidic softwater lakes, acidified softwater lakes have higher base cation concentrations, higher acidity, higher concentrations of nitrate, reduced levels of DOC, and greatly increased levels of several acid-soluble metals, especially Al. In the greater Sudbury area, levels of Cu and Ni are also elevated, especially in acidified lakes (Keller and Pitblado 1986).

These changes in chemistry had profound impacts on the physics of acidified lakes. Chromophoric DOC is the principal contributor to vertical attenuation of both visible and UV radiation in soft-water shield lakes (Scully and Lean 1995). With reductions in DOC levels, penetration by visible, but especially by UV radiation increased dramatically. The increased penetration by UV radiation has biological consequences, in the extreme eliminating UV-sensitive biota (eg., Persaud and Yan 2003). Increased penetration by visible light resulted in much warmer hypolimnia, deeper thermoclines, and earlier autumnal overturn in many acidified lakes (Yan 1983). It also permitted the development of sub-thermocline oxygen maxima.

There were major biological consequences of these changes in chemistry and physics. At pH values <6, the probability of presence of many species decreased as a direct result of their acid-sensitivity (Havens et al. 1993). These direct effects, and their indirect ramifications via alterations in competitive, predatory and parasitic linkages (Stenson and Eriksson 1989), led to reductions in diversity and alterations in structure at every trophic level of pelagic, profundal and littoral communities. Once the magnitude and severity of these changes became clear to the public and to industries, governments responded. New regulations in Canada, the USA and Europe mandated substantial reductions in S emissions. In the U.S.A. and particularly in Canada these reductions in emissions have been significant, and S deposition rates have fallen. In response, watershed biogeochemists are turning their attention to questions of critical acid loads that will permit water quality improvements (eg.Dillon and LaZerte 1992; Henriksen et al. 2002; Larssen et al. 2003), and ecologists are asking questions of the pace, extent, predictability, and regulation of recovery of biota from historical damage (Keller and Yan 1998; Yan et al. 2003; Doka et al. 2003).

Nowhere is recovery proceeding at a faster pace than in the greater Sudbury region of Ontario (Jeffries et al. 2003). While roughly 2 to 2.5 million tonnes of SO_2 were discharged annually from the Sudbury-based Ni and Cu smelters in the 1960s, these emissions were reduced by 5-fold during the 1970s to about 0.5 million tonnes per year, then by a further 2-fold by 1995 (Keller et al. 2003). Because of the great magnitude and the early dates of S-emission reductions in the Sudbury area recovery is more advanced in the Sudbury area than elsewhere in North America. In consequence there is a great international interest in the study of recovery of Sudbury-area ecosystems (eg. Gunn and Sandoy 2003).

In 1973, the Ministry of Environment initiated the Sudbury Environmental Study or SES (Michalski and Adamski 1974; Adamski and Michalski 1975; Scheider et al. 1975; Scheider and Dillon 1976; Scheider et al. 1976). Its initial objectives were: (1) to determine the causes of the unusual chemistry and biology of Sudbury lakes, (2) to conduct experiments to determine rate processes associated with local lake acidification as foundations of models that could be used to predict the consequences of changes in local emissions, and (3) to test reclamation techniques which could be selectively applied to important lakes (MOE 1982a). A major portion of the work in this study was conducted in four small, acid- and metal-contaminated lakes within the regional municipality of Sudbury, i.e. Middle, Hannah, Lohi and Clearwater Lakes. Liming and low-level fertilization experiments were conducted in these lakes to determine if biota could recover if acidity was reduced and if the food base was stimulated. As treatments, mixtures of $CaCO_3$ and $Ca(OH)_2$ were separately or jointly added to Middle, Hannah and Lohi Lakes between 1973 and 1975. Clearwater Lake served as the acidic control (Scheider et al. 1976; Yan and Miller 1982; Yan and Dillon 1982; Yan and Lafrance1982). Intensive investigations ceased on these lakes in 1979, but routine chemical, physical and plankton assessments of the lakes have continued on a monthly basis to the present day. The objectives of this latter two decades of monitoring were: (1) to determine if physical and chemical changes induced by acidification were reversed following reductions in acidity, (2) to determine the pace and extent of long-term recovery of the plankton in response to water quality improvements, and less importantly, (3) to determine if the limnological changes accompanying natural vs. liming-induced reductions in acidity are similar. In this report, we present the data needed to address the chemical and physical components of these three objectives.

The pre-1980 work on Middle, Hannah, Lohi, and Clearwater lakes (see Table 1 for geography and bathymetry) and three other intensive study lakes has been detailed

in MOE (1982a and b) and summarized in eight chapters of (Nriagu 1984). It is not our purpose to report the results of these earlier, experimental phases of the work. Readers who wish more details of this work should consult MOE (1982a) available from the Dorset Environmental Research Centre. There they will find reports that characterize the lakes (Yan and Miller1982) and their sediments (Dillon and Smith 1982), quantify the atmospheric inputs of ions, metals and nutrients (Jeffries et al.1982) to the lakes, characterize the hydrology (Scheider 1982), and chemistry of the lakes' streams (Jeffries et al 1982), document the responses of Middle and Hannah lakes to nutrient additions (Yan and LaFrance 1982), and of the three experimental lakes to additions of base (Yan and Dillon 1982), and use mass balance models to explain the lakes' chemistry (Dillon 1982). MOE (1982b) provides the 1973 to 1979 data from the lakes.

Clearwater Lake was not experimentally manipulated; however, its chemistry has changed substantially. Long-term reductions in the acidity and S concentrations of Clearwater Lake have provided unequivocal evidence of the potential for water quality improvements in the Sudbury area following reductions in S deposition (eg. Bodo and Dillon 1994; Jeffries et al. 2003).

2. Methods:

2.a. Study Lake Descriptions and Experimental Treatment.

Clearwater, Lohi, Middle and Hannah lakes are all located in the District of Sudbury, in the southwest portion of the regional municipality. Middle and Hannah Lakes are located a short distance from sites of heaviest industrial activity, while Clearwater and Lohi Lakes are a little further away (Table 1). With pH levels in the low 4's in the 1970s, all were heavily impacted by atmospheric deposition, to the point, for example, where all fish were extirpated. Johnson and

Owen (1966), Adamski and Michalski (1975), Scheider et al. (1975), Yan and Miller (1982), and Dillon et al. (1984), provide early descriptions of the unusual limnology and low biodiversity of the lakes.

Given the initial second objective of the SES program, whole lake fertilization and neutralization experiments were conducted (Table 2). The lakes were selected in hydrologic pairs with Hannah's outflow feeding Middle Lake, and Clearwater's outflow feeding Lohi Lake. In both cases the upstream lake served as the reference for downstream treatments. The first large-scale experiment was to compare the neutralizing ability of $Ca(OH)_2$ vs. a mixture of $Ca(OH)_2$ and $CaCO_3$; hence, slurries of $Ca(OH)_2$ were added to Lohi Lake, while the chemical mixture was added to Middle Lake in 1973. Given the rapid post-treatment decline in alkalinity in Lohi Lake in 1974, more $Ca(OH)_2$ was added in that year. As alkalinity again fell rapidly (Scheider et al. 1976), it was decided that the combination treatment was more effective, and in 1975, both $CaCO_3$ and $Ca(OH)_2$ were added to Lohi Lake. To provide further insights about recovery potential under conditions of extreme contamination, a mixed treatment was also applied to Hannah Lake in that year (Table 2). During the 1980s, the catchments of Hannah and Middle lakes were also limed as part of landscaping greening treatments (Lautenbach 1987), and this has prolonged circumneutral pH regimes in Hannah and Middle lakes (Yan et al. 1996). Exact quantities of base that were added to specific catchments by the municipality were not recorded. To determine if recovery could be augmented by modest fertilization, small amounts of phosphoric acid were added to the Middle and Hannah lakes in the mid-1970s (Table 2).

One final treatment was attempted in the lakes, i.e. the addition of fish. As summarized in Yan and Dillon (1982), Mike Powell from the Ministry of Natural Resources stocked 2500 young of the year smallmouth bass, 500 Iowa darters and 200 brook stickleback into Middle Lake in 1976, but failed to re-capture any fish in

the spring of 1977. Similarly, Powell stocked 1200 YOY brook trout, 1400 Iowa darters and 170 brook stickleback into Lohi Lake in 1976, but he subsequently concluded, based on re-capture efforts, that the stocking was completely unsuccessful. Follow-up netting and in situ toxicological work indicated that all of these fish had succumbed to metal, particularly Cu, toxicity (Powell et al. 1977; Yan et al. 1979). It was clear that despite pH levels >6, the neutralized lakes had not recovered the potential to support normal communities of fish or other biota by the end of the 1970s, although the progress of phytoplankton recovery was promising.

2.b Sampling and analytical methods.

Sampling frequencies, protocols and analytical methods used in the four lakes changed a few times during the 1970s, and changed again as we moved from the intensive experimental work of the 1970s to the subsequent long-term monitoring, 1979 was missed during this transition. The lakes were visited weekly between 1973 and 1978, with chemical parameters assayed on a weekly to fortnightly basis. After 1978, the lakes were normally sampled 5 to 6 times between May and October (excepting 1992, when the lakes were sampled only twice). MOE (1982b) and Scheider et al. (1975 and 1983) provide detailed sampling and analytical information for the 1973 to 1979 period, while Girard and Clark (2004) provide sampling and analytical information for the post-1979 period. Sampling was managed from Sudbury, between 1973 and 1978, from the MOE Dorset lab between 1979 and 1998, and by Sudbury after 1999.

Four methodological issues about the 1973 – 1978 data require careful consideration as we consider the three decades of limnological change in the lakes. Firstly, sampling began in the mid-summer of 1973, but all other years included spring samples as well. Hence, there may be some bias in 1973 annual means

because of the lack of vernal data. Secondly, water samples were collected 1 m below surface in 1974, but as composites of all depths in other years. This may bias the 1974 data for parameters exhibiting substantial variation with depth. Thirdly, N and P were assayed in a laboratory at the Sudbury sewage treatment plant between 1973 and 1978, and concentrations of TP in particular declined when analyses were moved to Dorset in 1979. We suspect the earlier TP analyses were to some extent contaminated. Finally, the sensitivity of analytical protocols for the major cations were increased by an order of magnitude between 1975 and 1977 (See Appendix 1). We suspect that the great variability and high levels of K and Mg in particular in the early 1970s reflect this analytical change. These concerns will be raised where appropriate throughout this report.

The focus of sampling in the four lakes in the last two decades has been to quantify long-term limnological recovery from acid and metal contamination. To do so we have quantified thermal profiles, transparency, water chemistry, phytoplankton and zooplankton during every sampling trip. We also quantified oxygen profiles since 1999, when Sudbury assumed management of the sampling program. Given the monthly sampling schedule, the data are best interpreted at annual time steps. Sampling and analytical details for the 1973 to 1979 period are provided in MOE (1982b). Since 1980, all samples have been collected at the deepest point in the main basin of each lake. Oxygen and temperature profiles were generated as described by Girard and Reid (1992), and the euphotic zone was estimated as twice the Secchi depth. Phytoplankton and chlorophyll samples were collected as composites, weighted for the diminution of stratum volume with depth, through the euphotic zone. Phytoplankton samples were preserved in the field in Lugol's iodine, and processed by Utermohl technique. Water chemistry and zooplankton samples were generated as composites through all depths. Using analytical protocols referenced in Appendix 1, water chemistry samples were analyzed for nutrients (NO_{3+2}-N, Total Kjeldahl-N, NH_4-N, total phosphorus (TP), dissolved inorganic (DIC), and organic, (DOC) carbon, and SiO_3), major ions (Ca, Mg, Na,

K, F, Cl, SO_4), acid-related parameters (pH, Gran and fixed endpoint alkalinity), metals (Cd, Cu, Ni, Pb, Zn, Fe, Mn, Al), and conductivity. Zooplankton composite samples were constructed by combining the contents of four vertical DRC net (McQueen and Yan 1993) hauls taken from pre-determined depths to the surface. In Clearwater, Hannah, Lohi, and Middle lakes, respectively, these hauls were of lengths 4, 8, 13 and 20 m; 2, 4, 6, and 7.5 m; 3, 6,10 and 18 m; and 3, 6,10 and 13 m. Animals were preserved in the field in a buffered, 4% sucrose formalin solution and subsequently identified, measured and counted using a semi-automated, counting and measuring system (Allen et al. 1994), as described by Yan et al. (1996). Zooplankton data were maintained in a relational database initially described by Pawson and Yan (1997), and modified somewhat since that time, by Martyn Futter (pers. comm.) of the MOE. Zooplankton and phytoplankton data will be summarized in upcoming data reports. Here our focus is to provide annual summaries of water chemistry, water temperature profiles, and, where possible, oxygen.

3. Results

3a. Brief Review of the 1970 - 1979 results: the whole-lake experiments

At least four decades of elevated levels of acid and metal deposition (Dillon and Smith 1982) left Clearwater, Lohi, Middle and Hannah lakes in very poor condition when studies began in 1973. The lakes had very unusual ionic composition in comparison with softwater lakes in low S deposition zones of Ontario. In particular, sulphate had replaced bicarbonate as the dominant anion. All base cation concentrations were elevated because of increased weathering rates, and most importantly, pH was very low, i.e. free hydrogen ion activity was very high (Table 3). Such acidity (pH near 4) is very unusual for all natural lakes except those with strong acid sources (eg. volcanic lakes or those draining acid-mine

spoils). Given their low pH, and proximity to industrial metal emission sources, levels of many metals were elevated, in particular Cu and Ni from smelter sources, and Al from elevated rates of weathering of bedrock and surficial geological material.

Dissolved organic carbon (DOC) is the principal attenuator of light penetration in oligotrophic Shield lakes (Scully and Lean 1995); and rates of photo-oxidation of DOC are greatly elevated at low pH. Hence, the water clarity of the lakes was very great, influencing both thermal and oxygen profiles. Secchi transparencies in 1973 averaged 11 m in Clearwater Lake and 8.8 m in Lohi lakes, and they were often on the lake bottom in Middle and Hannah lakes. In consequence the lakes had warm hypolimnia, early dates of autumnal overturn, and deep summer thermoclines (Yan 1983). In fact summer thermoclines were about twice as deep as one would predict from the sizes of the lakes (Yan and Miller 1982).

The additions of base had immediate effects on both physical and chemical limnology in Middle, Hannah and Lohi lakes. Acidity and concentrations of Cu, Ni, Mn, Al and Zn were reduced (Scheider et al. 1975, 1976). Transparency was reduced because of increases in concentrations of DOC, not increases in algal biomass. The reduced transparency resulted in a shallower mixing depth, cooler profundal temperatures and reduced depths of photosynthetic maxima (Yan and Dillon 1982). After base additions, phytoplankton community composition changed to more closely resemble that of circum-neutral communities, but circum-neutral zooplankton communities had not appeared by the end of the 1970s (Yan and Dillon 1982), nor indeed had they appeared by the early 1990s (Yan et al. 1996) in these lakes. Despite the water quality improvement, enclosure experiments conducted in the mid-1970s indicated that rainbow trout could not survive more than a few days in Middle and Lohi lakes after liming (Yan and Dillon 1982). Metal concentrations were still too high (Yan et al. 1979).

Additions of phosphorus to Middle and Hannah lakes (Table 2) in the mid-1970s did not raise TP levels above 15 ug.L^{-1}, but did lower NO_3 levels by 5 to 10 fold. Phytoplankton biomass increased in response, but composition was not predictable. Fertilization did not speed the recovery of typical non-acidic zooplankton communities.

3b.Changes in chemistry between 1973 and 2001

This report tabulates the changes in water chemistry data averaged at annual time steps in the four study lakes between 1973 and 2001. Given our monthly sampling schedule, seasonal changes are not provided, but sample size and minimum and maximum values for each year are presented. The main data tables are split into panels for: (a) cations, (b) anions, (c) conductivity and sums of equivalent concentrations of anions and cations, (d) pH and dissolved inorganic carbon, DIC, (e) N species, TP, and SiO_3, (f) water transparency (Secchi depth), and its main determinants, i.e.DOC and chlorophyll, and (g) the metals Cu, Ni, Zn, Mn, Fe and Al. Highlights of these tables are also graphed where it helps illustrate dominant trends. Following the chemical summary we provide summaries of changes in the thermal and optical regimes of the four lakes. Oxygen profiles were generated from 1973 to 1979 (see MOE 1982b). The more recent oxygen profiles are summarized here.

While the data presentation could have been organized in several ways, we found it most useful to proceed one lake at a time, beginning with Clearwater Lake, the reference lake for the 1970's manipulations, then proceeding to Lohi Lake to which base only was added, and ending with Middle and Hannah lakes, which received

both base and phosphorus additions. Each additional manipulation resulted in a more complicated series of chemical and physical changes in the lakes.

3bi Clearwater Lake

There were gradual, generally monotonic changes in most water quality parameters in Clearwater Lake, and the majority of these changes indicate recovery from historical acidification and metal contamination. Ionic strength and conductivity fell in the lake, especially during the 1990s (Figure 6b). Concentrations of Ca fell by 50% during the 1990s (Figure 6a). Mg and K levels were high and variable in the first few years, and we judge these values to be suspect for reasons listed in the methods. After 1975, Mg levels fell substantially while K levels fell gradually and continuously to the present day. In contrast Na levels doubled (Figure 6a), almost certainly in response to winter de-icing activities on roads in the watershed. As Cl levels increased by 7-fold over the same time period (Table 4b, Figure 6b), it is clear that reduced export of Na from the catchment in response to reduced weathering rates was more than offset by increased application of road salt. While Cl levels rose, SO_4 concentrations fell by three-fold from 28 $mg.L^{-1}$ in 1973 to 10.7 $mg.L^{-1}$ in 2001 (Table 4b, Figure 6b). There were large increases in alkalinity (Table 4b) and in dissolved inorganic carbon (Table 4d) associated with declining SO_4 concentrations (Figure 6b). Alkalinity was negative for the first 6 years of monitoring, then increased steadily to almost 3 $mg.L^{-1}$ as $CaCO_3$ by the end of the study. In response to all of these changes, the pH of the lake increased from 4.3 in 1973 to 6.4 in 2001 (Figure 6a), rising above pH 6.0, the threshold normally assumed to permit ecological recovery (Holt and Yan 2003). While the pH of many lakes is improving in Ontario, the magnitude of the Clearwater Lake change is unusual (Jeffries et al. 2003).

All metals concentrations assayed in Clearwater Lake fell substantially. Most dramatic were the declines in Al (Figure 6c) which fell by more than 20-fold, from 400-500 to roughly 20 ug.L^{-1}. Cu and Ni, the two metals most closely associated with the smelters declined by 10- and 5-fold respectively, while Zn and Mn levels also fell by 5-fold (Figure 6c). The pattern for Fe, a metal much influenced by redox reactions was more variable, but it too declined by roughly 3-fold over the three decades (Figure 6c).

The changes in acidity were correlated with changes in nitrogen and carbon concentrations and speciation, but not with changes in total phosphorus (TP). Concentrations of TP fluctuated from 3 to 6 $\mu g.L^{-1}$ in the lake on an annual basis (Table 4e, Figure 6e). This is quite a typical concentration and degree of fluctuation for Ontario lakes (Dillon unpub data), and we must also note that TP levels fell when the analyses were moved from Sudbury to Toronto in 1979. We think the slight increase in TP levels evident from 1979 to the current day is real, while the 1979 fall is probably not. The patterns with nitrogen are clearer. Total Kjeldahl N concentrations approximately doubled over the time series from about 100 to 200 $\mu g.L^{-1}$ (Figure 6d). Because NH_4-N concentrations were relatively stable, it is clear that organic nitrogen concentrations (TKN – NH_4) roughly doubled as well (Figure 6d). Much of the increased organic nitrogen was attributable to a decline in NO_3, which approximately halved by 2001 from its 1970's levels (Table 4e); however, the reduction in nitrate doesn't fully account for the increase in organic-N. This suggests either that N loading to the lake may have increased and/or N loss rate from the lake may have declined over time. The overall result of these changes in N speciation in the lake was quite dramatic. Roughly half of the dissolved nitrogen was inorganic in Clearwater Lake when the program began, but by 2001, only about 15% of the total nitrogen was inorganic on an annual basis (Figure 6d).

Concentrations of both dissolved and suspended material that attenuate light increased over time in the lake. We began routine measurements of DOC in 1981. Given that the 1981 pH was very acidic, we assume that the DOC concentrations in the 1970's would have been similar, or a bit lower. Between 1981 and 2001 DOC levels increased by 6-fold, from 0.4 to 2.4 $mg.L^{-1}$ (Table 4f, Figure 6e). Total chlorophyll concentrations also increased in the lake, particularly during the 1990's. Concentrations were <1 $mg.L^{-1}$ prior to 1990, 1 – 2 $mg.L^{-1}$ in the mid-1990s, and >2 $mg.L^{-1}$ after 1998 (Table 4f, Figure 6e). These increases in DOC and chlorophyll were associated with substantial reductions in water transparency. Secchi transparency fell in a fairly linear manner throughout the time series, from around 10 m in the early 1970s, to 7 m on average by 2001 (Figure 6e).

There were also substantial changes in the thermal regime of Clearwater Lake which we believe is attributable changes in internal (transparency) and external (wind speed) drivers. Average surface temperatures did not increase in the lake over time, but the linear sub-epilimnetic temperatures decline was dramatic, and the mid-summer thermocline depth rose by about 4 m between 1973 and 2001 (Figure 6f). As a consequence of reduced light penetration, the maximum heat content and average lake temperature both declined in the lake (Figure 6g). Hence, during three decades of global warming (meteorological data are summarized in Appendix 2) the volume-weighted average temperature of Clearwater Lake actually declined by about 2°C, from about 21 to 19°C. The development of physical models needed to explain these changes in thermal regimes are beyond the scope of this data report. Nonetheless, the time series indicated that windspeeds declined during the first half of the Clearwater record (Appendix 2), but were fairly constant in the second half. In contrast DOC and chlorophyll were fairly constant in the first half of the time series but increased in the second half. Hence, we believe that the dominant drivers responsible for the changes in hypolimnetic temperatures changes from wind driven mixing in the 1970's and early 1980's, to water

transparency in late 1980s and 1990s. Figures 6h and 6i provide the raw temperature profiles and depths of mid-summer mixing layers in the lake over the last thirty years.

While we can only compare oxygen data from the 1970's with the last four years, there also appear to have been changes in oxygen in Clearwater Lake, associated with the other limnological changes. During the 1970s, oxygen profiles were positive heterograde in the lake, with metalimnetic maxima of about 10-13 $mg.L^{-1}$ at depths of 14 – 16 m. Levels just above bottom never fell to < 4 $mg.L^{-1}$ at any time (MOE 1982b). In contrast, between 1998 and 2001, metalimnetic maxima were observed at shallower depths of around 12 m, consistent with reductions in water clarity, and bottom water O_2 concentrations routinely fell below 4 $mg.L^{-1}$ in August and September (Figure 6j), despite cooler hypolimnetic temperatures. Microbiol respiration rates are temperature dependent, hence some or all of three factors must account for decreases in bottom oxygen concentrations: longer periods of stratification, reduced rates of hypolimnetic oxygen production given lower water clarity, and, perhaps elevated rates of organic loading to the hypolimnion given the higher chlorophyll concentrations.

3bii Lohi Lake

There were four recognizable stages of acidity in the recent limnological history of Lohi Lake: (1) the 1973 pre-liming phase, (2) the 1974 to 1977 liming period, followed by (3) the abrupt re-acidification in 1978 that lasted until the early 1990s, and finally, (4) the gradual de-acidification of the 1990s (Figure 7a, see the pH panel). In 1973, prior to liming, the pH of the lake was 4.3. The pH was raised to just over 6 by additions of base in the fall of 1973 and in 1974 and 1975, but it fell to about 4.75 shortly after base additions ceased, where it remained until about

1991. From that point on, lake pH rose monotonically reaching 6 by the mid-1990s (Figure 7a).

The addition of base in the 1970s produced similar changes in the physics and chemistry of Lohi Lake as did its subsequent natural recovery from re-acidification in the 1990s, with two exceptions. Firstly, when pH was elevated by additions of neutralizing agents, Ca (Figure 7a) and DIC concentrations and alkalinity all increased (Figure 7b), but when acidity declined naturally during the 1990s, the increases in DIC and alkalinity were accompanied by Ca declines (Figure 7a). Secondly, the changes associated with the natural recovery in Lohi lake were more substantial than those associated with the liming experiments, eg. pH and DIC changes were larger in the 1990s than after liming (Figure 7a, b). Concentrations of Al, Cu, Ni and Mn declined in the mid-1970's after additions of base, but declined more in the 1990s when acidity fell naturally (Figure 7c). This pattern of greater change in the 1990's was repeated for nitrate (Figure 7d), for water transparency (Figure 7e) and for thermal regimes (Figure 7f).

Changes in ionic content of Lohi Lake reflected base additions, road salt additions, and the 1990s natural recovery, in part attributable to the water quality improvements in the upstream Clearwater Lake. Ca levels rose by 50% in response to base additions. They then fell to pre-addition levels by 1980, then fell by an additional 50% through the 1990s (Figure 7a), as they had in Clearwater Lake. If we exclude the first two years of less reliable K and Mg data, Mg levels also declined through the 1990s in Lohi Lake, while K levels were quite stable. Na levels tripled likely in response to de-icing and dust control applications (Dillon 1982). Anions responded in a similarly explicable manner. Sulphate concentrations declined fairly monotonically in response to reduced local emissions, rates of decline being greatest from 1973 to 1983, then again from 1990 to 1995 (Figure 7b). Alkalinity and DIC were both elevated by base additions.

They then fell and were fairly stable during the 1980s, but rose steadily during the 1990s (Figure7b).

The patterns in metal concentrations were very dramatic. As previously noted (Scheider et al. 1975, Yan and Dillon 1982), levels of all metals were reduced by additions of base, by 75% for Cu, 30% for Al, and 50% for Zn, Ni, and Mn. However, these reductions were ephemeral, and all metals returned to pre-liming levels when the lake re-acidified. The more recent metal reductions were much more dramatic and longer-lasting than those induced by base additions (Figure 7c, Table 5g). Al, Zn, Fe and Mn levels are now at levels typical of remote Shield lakes. Cu and Ni levels have fallen to about 10 and 25 $ug.L^{-1}$, respectively, levels that remain above background levels, even though the improvement in water quality is very substantial. Without loading data, we cannot determine the contribution of falling local metal emissions to these patterns, but we assume this influence is substantial.

Recent changes in N speciation and in trophic indicators in Lohi Lake are similar to those of Clearwater Lake. Inorganic N levels, particular NO_3-N levels, have fallen in the 1990s, while organic N levels have increased substantially. Indeed recent total N levels are similar to those prior to base additions, but the ratio of inorganic to organic N has fallen from 50 to 15% as in Clearwater Lake (Figure 7d, Table 5e). As in Clearwater Lake, TP concentrations have been quite variable, but both DOC and chlorophyll concentrations have mirrored changes in alkalinity. Levels increased slightly after base additions, declined when the lake re-acidified, then increased steadily and dramatically beginning in the late 1980s (Figure 7e, Tables 5e and 5f). Excluding a short-lived, November 1973, post-liming spike in water clarity, the water clarity patterns reflect the changes in DOC, and recently in chlorophyll. Secchi transparency was 8m prior to liming. It fell to 6 m during the three liming years, then it increased when the lake re-acidified in 1978/9, only to

decline again in the late 1980s, because of the DOC and/or phytoplankton biomass rise (Figure 7e).

Finally, the changes in thermal regimes reflected the changes in transparency. Summer bottom waters were "warm", i.e. 9-11°C, prior to liming in 1973, and after re-acidification from 1982-1986. In contrast bottom waters were colder, i.e. <9°C, during the liming years, and they have become cold again during the recent recovery phase (Figure 7f). The mid-summer thermocline depth and average lake temperature have also responded to changes in transparency. When the lake re-acidified after liming, the mid-summer thermocline depth deepened by 1 –2 m falling to 9-10m, but it has since risen by about 3 m, although the recent inter-annual variation in thermocline depth is substantial (Figure 7f). As in Clearwater Lake, volume-weighted whole lake temperature has fallen by about 2°C, from the early 1980's maxima of about 22°C. Raw temperature profiles and midsummer thermocline depth calculations are provided in Figures 7h and 7i. Recent oxygen profiles are provided in Figure 7j.

3biii Middle Lake.

The chemical and physical limnology of Middle Lake responded to the planned liming and fertilization experiments, to the late 1980s catchment liming, to road salt additions, and to the widespread reduction in acid and metal deposition in the Sudbury area. It is not possible to clearly delineate specific, single causes of limnological change given this complexity.

A slurry of $Ca(OH)_2$ and $CaCO_3$ was added to Middle Lake from September to November of 1973, and parts of its catchment were limed, fertilized and planted as part of a 1980s regional re-greening program (Lautenbach 1987). These watershed additions are most clearly seen in the increase in Ca (9.8 - 14.0 $mg.L^{-1}$) and pH (4.4

- 5.86) in the lake in 1973 - planned increases - and the more modest increase in pH and Ca in the later 1980s – unplanned increases (Table 6a, Figure 8a, Table 6a). Unlike Lohi Lake, Middle Lake did not re-acidify in the late 1970s; indeed it never re-acidified. This we attribute to initial greater volumetric base additions, the addition of excess carbonate that provided a residual buffer source, the 1975 liming of Hannah Lake, Middle Lake's principal water source, the liming of the lake's watershed in the 1980s, reductions in acid deposition, and perhaps to watershed activities such as the construction of the Hwy 17 bypass within the watershed of the lake. It must be de-icing operations on this bypass that are responsible for the 17 fold increase in lakewater Na (Figure 8a), and a 47 fold increase in Cl (Figure 8b).

The changes in anion concentrations were as dramatic as those for cations. Sulphate concentrations declined by 3 fold, probably largely attributable to decreased S input. Both alkalinity and measured DIC concentrations increased dramatically, as did Cl, in consort with Na (Table 6b, Figure 8b). While conductivity had decreased in Clearwater and Lohi Lakes, it increased dramatically in Middle Lake, mainly as a result of increased salt content (Figure 8a, 8b).

The pattern of long-term reduction in metal concentrations, seen in both Clearwater and Lohi Lake, was continued in Middle Lake. The largest point-in-time metal concentration decrease certainly accompanied the liming of the lake in the fall of 1973. This treatment led to an immediate 7-fold reduction in Cu from 500 to 66 $ug.L^{-1}$ and 3-fold reduction in Ni levels from 1060 to 350 $ug.L^{-1}$ in the lake (Table 6g, Figure 8c). Thereafter, metal levels continued to decline for many years, presumably because of reduced deposition to the watershed and/or increased catchment retention. By 2001, Cu and Ni levels had fallen to 24 and 127 $ug.L^{-1}$, respectively, a further 3-fold reduction from the post-liming values.

Concentrations of Al, Zn, Mn and Fe also fell over time, reaching levels that are typical of non-acid lakes in south-central Ontario (LaZerte 1986).

Additions of phosphoric acid raised TP levels in Middle Lake, but only between 1976 and 1978. Thereafter TP levels were quite constant at around 5 $\mu g.L^{-1}$ (Figure 8e, Table 6e). The liming and fertilization were accompanied by increases in NH_4-N and organic nitrogen, and by decreases in NO_3-N levels in the lake (Figure 8d), during the 1970s. However, for the last two decades, average NO_3-N and NH_4-N levels have been fairly stable, at around 10-30 $\mu g.L^{-1}$, while organic nitrogen levels have increased gradually by about 30%, from about 200 to 300 $\mu g.L^{-1}$. The result is a long-term dramatic change in N speciation from about 20% organic-N in 1973 prior to liming to 90% organic-N over the last decade (Figure 8d).

Conventional trophic status indicators were influenced by all treatments. TP concentrations were elevated above 10 $\mu g.L^{-1}$ by fertilization, and these treatments were probably responsible for raising chlorophyll levels and reducing Secchi transparency in the mid-1970s. Thereafter, TP and chlorophyll varied in apparent synchrony but without a long-term trend (Figure 8e). Secchi depth was 10 m before liming, and fell to 2-3 m during the fertilization years. Thereafter it has varied between 3 and 5 m with no apparent long-term trend.

It is rare that Shield lakes switch thermal stratification classes, but Middle Lake has undergone such a switch. Prior to liming, with its great water clarity, Middle Lake stratified weakly if at all, with surface to bottom temperatures differing by only 2°C in mid-summer (MOE 1982b). Liming and fertilization changed this completely. In 1974 and thereafter, the lake has stratified strongly, with bottom temperatures of only 5-10°C in mid-summer (Figure 8f). Furthermore, over the last 25 years, there had been no trend in midsummer surface water temperatures, which averaged

around 23°C, but mid-summer bottom water temperatures have fallen by about 2°C, and summer stratification depths have risen by about 1m (Figure 8f). As a result of the modest trends towards a cooler and thicker hypolimnion, volume-weighted mean lake temperature actually declined by about 1.5°C from 1973 to 2001. While this change was significant (Figure 8g), it was a more modest temperature drop than in Clearwater and Lohi Lakes. Clearly, 1973 was the year the lake was unstratified and warmest (Figure 8g). However the long-term cooling trend does not disappear when the 1973 data are removed. Temperature profiles, stratification depths and recent oxygen profiles for Middle Lake are provided in Figure 8h to 8j.

3biv Hannah Lake

Hannah Lake was influenced by the 1975 liming and 1976 to 1978 fertilization experiments, by the 1980s catchment liming, by road salt additions, and by long-term reductions in local metal and SO_2 emissions. It is also the shallowest of the four study lakes and this influenced its thermal time series.

Additions of base to the lake in June of 1975 raised the pH from the mid-4s to 7, and the Ca concentration from 12 to 20 $mg.L^{-1}$ (Figure 9a, Table 7a) Thereafter Ca levels fell until the mid-1980s, when both pH and Ca were raised again, most likely by watershed lime and nutrient additions attributable to regional restoration efforts. A 1995 decline in Ca, Mg, K and Na (Figure 9a) is unexplained, but without quantified major ion loading data, such an explanation is difficult to provide. As in the other lakes, SO_4 declined by about 3-fold in Hannah lake, but as the lake is the closest to emission sources, and well mixed, perhaps lowering sulphate reduction rates, SO_4 concentrations remained high, at about 20 $mg.L^{-1}$. Both DIC and alkalinity levels have increased dramatically, but the principal increases

occurred in 1975, associated with base additions, and during the 1980s. The additions of phosphorus from 1976 to 1978 didn't appear to have a large impact on alkalinity (Figure 9b), even though nitrate reduction is an alkalinity generator. As in all four lakes, road deicing increased salt concentration, but in Hannah Lake these activities have had a huge effect, with Cl levels increasing by forty-fold from 1973 level reaching 106 $mg.L^{-1}$ by 2001.

As in Middle Lake, metal concentrations in Hannah Lake declined immediately in response to the 1975 liming, then more gradually over the next 25 years. Because Hannah Lake is closest to the emission sources, it had the highest metal levels of the four lakes. Comparing 1974 to 1976 annual means, the 1975 additions of base reduced Al levels by 17-fold from 1100 to 66 $\mu g.L^{-1}$, Cu levels by 21-fold from 1110 to 52 $\mu g.L^{-1}$, and Ni levels by 4 fold from 1870 to 427 $\mu g.L^{-1}$ (Table 7g). Thereafter, levels continued to decline, reaching 14, 24, and 139 $\mu g.L^{-1}$, respectively by 2001. Levels of Zn and Mn were also dramatically reduced by the additions of lime, and continued to fall thereafter (Figure 9c). Fe time series exhibited much less long-term pattern.

Additions of phosphorus raised TP levels in 1977 and 1978, but otherwise there was little long-term pattern in the TP time series (Figure 9e). In contrast there were dramatic long-term changes in the nitrogen time series. Prior to base additions, levels of nitrate were very high, at 500-700 $\mu g.L^{-1}$ (Table 7e), and 80% of lakewater nitrogen was inorganic. Organic-N levels increased during the fertilization years (Figure 9d), then remained rather stable at 250 to 350 $\mu g.L^{-1}$ until the present day. Concurrently, NH_4 remained low, while NO_3 levels fell fairly monotonically until the mid-1990s. Unlike Clearwater and Lohi lakes, total-N levels are currently half of their pre-liming values, at around 300 $\mu g.L^{-1}$, only 10% of which is inorganic.

Secchi transparency was reduced by additions of base, then further by fertilization, but since the late 1970s it has not exhibited any long-term trend, averaging between 3.5 to 5 m. This lack of long-term trend is consistent with relatively stable post-fertilization values of TP, DOC, and chlorophyll (Figure 9e). Bottom water temperatures did cool over the time series in Hannah Lake (Figure 9f), but they did not cool nearly as much as in the other lakes, nor was the hypolimnion of appreciable thickness, given the lake's depth. Hence, unlike the other three lakes, while they were negative, the long-term trends in summer heat income, heat content, and volume weighted-mean lake temperature were not significant in Hannah Lake (Figure 9g). Temperature profiles and stratum depth boundaries in Hannah Lake are shown in Figures 9h and 9i. While the changes in volume-weighted averages were not significant, it is clear that stratification occurred more often later, than earlier in the time series.

While the data are few, there have apparently been quite dramatic changes in oxygen profiles in Hannah Lake. Prior to 1980, oxygen profiles were almost always orthograde, and bottom water concentrations never fell below 7 $mg.L^{-1}$. Indeed they were more commonly at saturation. In contrast, by the late 1990s, oxygen profiles were usually positive heterograde in the summer and early fall (Figure 9j), and profundal concentrations were often <2 $mg.L^{-1}$. Given the modest, if any change in TP and chlorophyll, we attribute the change in oxygen to the recent reduced mixing evident in the temperature profiles.

Literature Cited:

Adamski, J. M. and M. F. P. Michalski (1975). "Reclamation of acidified lakes- Middle and Lohi, Sudbury, Ontario." Verh. Internat. Verein. Limnol. **19**: 1971-1983.

Allen, G., N. D. Yan, and W.T. Geiling (1994). "ZEBRA2- Zooplankton enumeration and biomass routines for APIOS: a semi-automated sample processing system for zooplankton ecologists." Ont. Min. Env. report, 44 pp + appendices

Almer, B., W. Dickson, C. Ekstrom, E. Hornstrom and U. Miller (1974). "Effects of acidification on Swedish lakes." Ambio **3**: 30-36.

Bodo, B. and P. J. Dillon (1994). De-acidification trends in Clearwater Lake near Sudbury, Ontario: 1973-1992. Stochastic & Statistical Methods in Hydrol. Envir. Eng. TIME SERIES analysis in hydrology and Environmental Engineering. A. I. M. K.W. Hipel, U.S. Panu and V.P. Singh (eds.). **3:** 285-298.

Cox, E.T. 1978. Counts and Measurements of Ontario Lakes, Watershed Unit Summaries Based on Maps of Various Scales by Watershed. Min. of Nat. Resources.

Cronan, C. S. and C. L. Schofield (1979). "Aluminum leaching response to acid precipitation: effects on high-elevation watersheds in the northeast." Science **204**: 304-306.

Cumming, B. F., J. P. Smol, J. C. Kingston, D. F. Charles, H.J.B. Birks, K. E. Camburn, S. S. Dixit, A. J. Uutala, A. R. Selle(1992). "How much acidification has occurred in Adirondack region lakes (NewYork) since preindustrial times?" Can. J. Fish. Aquat. Sci. **49**: 128-141.

Dillon, P. J. (1982). Mass balance models: an explanation of the observed chemistry of lakes nears Sudbury, Ontario. Sudbury Environmental Study: Studies of lakes and watersheds in the Sudbury area: final limnological report. SES 009/2. Anon.

Dillon, P. J. and B. D. LaZerte (1992). "Response of the Plastic Lake catchment, Ontario, to reduced sulphur deposition." Env. Pollut. **77**: 211-217.

Dillon, P. J. and P. J. Smith (1982). Sediment chemistry and rates of sedimentation in lakes near Sudburty, Ontario. Sudbury Environmental Study: Studies of lakes and watersheds in the Sudbury area: final limnological report. SES 009/2.

Dillon, P. J., N. D. Yan, and H.H. Harvey (1984). "Acidic deposition: effects on aquatic ecosystems." CRC Crit. Rev. Environ. Contr. **13**: 167-194.

Doka, S. E., D. K. McNicol, M. L. Mallory, I. Wong, C. K. Minns and N. D. Yan (2003). "Assessing recovery of biotic richness and indicator species due to changes in acidic deposition and lake pH in five areas of southeastern Canada." Env. Monitor. Assess. **88**: 55-101.

Driscoll, C. T., J. P. Baker, J. J. Bisogni, Jr, and C. L. Schofield (1980). "Effect of aluminum speciation on fish in dilute acidified waters." Nature **284**: 161-164.

Fee, E. J., R. E. Hecky, S. E. M. Kasian and D.R. Cruikshank (1996). "Effects of lake size, water clarity, and climatic variability on mixing depths in Canadian Shield lakes." Limnol. Oceanogr. **41**: 912-920.

Gennings, C., L. A. Molot, and P.J. Dillon (2001). "Enhanced photochemical loss of organic carbon in acidic waters." Biogeochem. **52**: 339-354.

Girard, R. and R. A. Reid. (1992). Dorset Research Centre study lakes: sampling methodology (1986-1889) and lake morphometry. Dorset, Ont. Min. Environ., 33 pp + appendices.

Girard, R. E., B. J. Clark, N.D. Yan, R.A. Reid, S.M. David and J.G. Findeis. (2004). History of Chemical, Physical and Biological Sampling Methods, Sample locations and Lake morphometry for the Dorset Environmental Science Centre (1973 - 2003), Ontario Ministry of the Environment.,: 96 pp + appendices.

Gunn, J. M. and S. Sandoy (2003). "Introduction to the Ambio Special Issue on Biological Recovery from Acidification: the Northern Lakes Recovery Study." Ambio **32**(3): 162-164.

Havens, K. E., N. D. Yan, and W. Keller (1993). "Lake acidification: effects on crustacean zooplankton populations." Env. Sci. Technol. **27**: 1621-1624.

Helmer, E. H., N. R. Urban and S. J. Eisenreich (1990). "Aluminum geochemistry in peatland waters." Biogeochem **9**: 247-276.

Henriksen, A., P. J. Dillon, and J. Aherne (2002). "Critical loads of acidity for surface waters in south-central Ontario, Canada: regional application of the steady-state water chemisty (SSWC) model." Can. J. Fish. Aquat. Sci. **59**: 1287-1295.

Holt, C. A., N.D. Yan and K. Somers (2003). "pH 6 as the threshold to use in critical load modeling for zooplankton community change with acidification in lakes of south-central Ontario: accounting for morphometry and geography." Can. J. Fish. Aquat. Sci. **60**: 151-158.

Jeffries, D. S. (1982). Atmospheric deposition of major ions, nutrients and trace metals in the Sudbury area. Sudbury Environmental Study: Studies of lakes and watersheds in the Sudbury area: final limnological report. Report SES 009/82. Anon., Ontario MInistry of the Environment.

Jeffries, D. S., T.A. Clair, S. Couture, P.J. Dillon, J. Dupont, W. Keller, D.K. McNicol, M.A. Turner, R. Vet and R. Weeber (2003). "Assessing the recovery of lakes in southeastern Canada from the effects of acidic deposition." Ambio **32**: 176-182.

Jeffries, D. S., W.A. Scheider and W.R. Snyder (1982). Stream chemistry: geochemical interactions of watersheds with precipitation near Sudbury, Ontario. Sudbury Environmental Study: Studies of lakes and watersheds in the Sudbury area: final limnological report. SES 009/2. Anon., Ontario Ministry of the Environment.

Johnson, M. G. and G. E. Owen (1966). Biological survey of the streams and lakes of the Sudbury area: 1965, Ont. Wat. Res. Comm.**:** 46.

Keller, W. and J. R. Pitblado (1986). "Water quality changes in Sudbury area lakes: a comparison of synoptic surveys in 1974-1976 and 1981-1983." Wat. Air Soil Pollut. **29**: 285-296.

Keller, W. and N. D. Yan (1998). "Biological recovery from acidification: zooplankton communities as models of patterns and processes." Restoration Ecol **6**: 364-375.

Keller, W. B., J. H. Heneberry, and S.S. Dixit (2003). "Decreased acid deposition and the chemical recovery of Killarney, Ontario, Lakes." Ambio **32**: 183-189.

Kopacek, J., J. Hezjlar, J. Kara and P. Poneel. 2002. Photochemical, chemical, and biological transformaitons of dissolved organic carbon and its effects on alkalinity production in acidified lakes. Limnol. Oceanogr. **48**: 106-117.

Larssen, T., C. Brereton, and J.M. Gunn (2003). "Dynamic modelling of recovery from acidification of lakes in Killarney Park, Ontario, Canada." Ambio **32**: 244-248.

Lautenbach, W. E. (1987). "The greening of Sudbury." J. Soil Wat. Conserv. **42**: 228-231.

LaZerte, B. (1986). "Metals and acidification: an overview." Wat. Air Soil Pollut. **31**: 569-576.

McQueen, D. J. and N. D. Yan (1993). "Metering filtration efficiency of freshwater zooplankton hauls: reminders from the past." J. Plank. Res. **15**: 57-65.

Michalski, M. F. P. and J. Adamski (1974). "Reclamation of acidified lakes Middle and Lohi, Limnological aspects 1973." Ontario Industrial Waste Conf. Proc.: 163-175

Ontario Ministry of the Environment (MOE) 1982a. Sudbury Environmental Study: Studies of lakes and watersheds near Sudbury, Ontario: final limnological report. SES 009/82.

Neary, B. P. and P. J. Dillon (1988). "Effects of sulphur deposition on lake-water chemistry in Ontario, Canada." Nature **333**: 340-343.

Nriagu, J. (1984). Environmental Impacts of Smelters., J. Wiley & Sons, Inc.

Ontario Ministry of the Environment (MOE) 1982b. Sudbury Environmental Study: Studies of lakes and watersheds near Sudbury, Ontario: final limnological report. Supplementary volume to SES 009/82.

Pawson, T. and N. D. Yan (1997). Revised zooplankton sample archive and database design for the Dorset Environmental Science Centre, Ont. Min .Env., Dorset Env. Sci. Centre: 40.

Perez-Fuentetaja, A., P.J. Dillon, N.D. Yan, and D.J. McQueen. 1999. Significance of dissolved organic carbon in the prediction of thermocline depth in small Canadian Shield lakes. Aquat. Ecol. **33**: 127 - 133.

Persaud, A. D. and N. D. Yan (2003). "UVR sensitivity of Chaoborus larvae." Ambio **32**: 219-224.

Powell, M. J. (1977). An assessment of brook trout planting in a neutralized lakes as compared to four other Sudbury area lakes. Sudbury, Ont. Min. Nat. Res. , Fish, Wildlife Br.: 32.

Rudd, J. W. M., C. A. Kelly, D. W. Schindler and M. A.Turner (1988). "Disruption of the nitrogen cycle in acidified lakes." Science **240**: 1515-1517.

Scheider, W. and P. J. Dillon (1976). "Neutralization and fertilization of acidified lakes near Sudbury, Ontario." Proc. 11th Can. Symp. Wat. Pollut. Res. Can.: 93-100.

Scheider, W. A. (1982). Components of the water balance of lakes near Sudbury, Ontario. Sudbury Environmental Study: Studies of lakes and watersheds in the Sudbury area: final limnological report. SES 009/2. Anon. Dorset, Ontario Ministry of the Environment.

Scheider, W. A., R. A. Reid, B. A. Locke and L. D. Scott. (1983). Sutides of lakes and watersheds in Muskoka-Haliburton, Ontario: methodology (1976-82). Ont. Min. Envir. Data Report DR83/1.

Scheider, W. A., J. Adamski, and M. Paylor (1975). Reclamation of acidified lakes near Sudbury, Ontario. Toronto, Ontario Ministry of the Environment, 129 pp.

Scheider, W. A., B. Cave, and J. Jones (1976). Reclamation of acidified lakes near Sudbury by neutralization and fertilization. Toronto, Ontario Ministry of the Environment, 48 pp.

Schindler, D. W. M. A. Turner M. P. Stainton, G. A. Linsey. 1986. Natural sources of acid neutralizing capacity in low alkalinity lakes of the Precambrian Shield. Science. **232**: 844-847.

Scully, N. M. and D. R. S. Lean (1995). "The attenuation of ultraviolet radiation in temperate lakes." Arch. Hydrobiol. Beih. Ergebn. Limnol. **43**: 135-144.

Stenson, J. A. E. and M. O. G. Eriksson (1989). "Ecological mechanisms important for the biotic changes in acidified lakes in Scandinavia." Arch. Environ. Contam. Toxicol. **18**: 201-206.

Yan, N. D. (1983). "The effects of changes in pH on transparency and on thermal regimes of Lohi Lake, near Sudbury, Ontario." Can. J. Fish. Aquat. Sci. **40**: 621-626.

Yan, N. D. and P. J. Dillon (1982). "Experimental neutralization of lakes near Sudbury, Ontario". Sudbury Environmental Study: Studies of lakes and watersheds in the Sudbury area: final limnological report. SES 009/2, Ontario Ministry of the Environment report, Dorset, ON.

Yan, N. D., R. E. Girard, and C.J. LaFrance (1979). Survival of rainbow trout, *Salmo gairdneri*, in submerged enclosures in lakes treated with neutralizing agents near Sudbury, Ontario, Ont. Min. Environ., 26 pp.

Yan, N. D., W. Keller, K.M. Somers, T.W. Pawson and R.E. Girard (1996). "The recovery of crustacean zooplankton communities from acidification: comparing manipulated and reference lakes." Can. J. Fish. Aquat. Sci. **53**: 1301-1327.

Yan, N. D. and C. Lafrance (1982). "Experimental fertilization of lakes near Sudbury, Ontario". Sudbury Environmental Study: Studies of lakes and watersheds in the Sudbury area: final limnological report. SES 009/2. Ontario Ministry of the Environment report, Dorset, ON.

Yan, N. D., B. Leung, W.(B.) Keller, S.E. Arnott, J.M. Gunn and G.G. Raddum (2003). "Developing a conceptual framework for the recovery of aquatic biota from acidification: a zooplankton example." Ambio **32**: 165-169.

Yan, N. D., and G.E. Miller (1982). "Characterization of lakes near Sudbury, Ontario". Sudbury Environmental Study: studies of lakes and watersheds near Sudbury Ontario: final limnological report, Ontario Ministry of the Environment report, Dorset, ON.

Table 1: Summary of geographic and morphometric data for the four study lakes (from Yan and Miller 1982). The lakes are all in the District of Sudbury.

Geographic or morphometric variable	Hannah	Middle	Lohi	Clearwater
Latitude	46° 27'	46° 26'	46° 23'	46° 22'
Longitude	81° 02'	81° 02'	81° 02'	81° 03'
Elevation (msl)	285	284	282	285
Topographic map reference number	41I6	41I6	41I6	41I6
Tertiary watershed identifier*	2C F8	2C F8	2C F5	2C F5
County/Township	Broder	Broder	Broder	Tilton/Broder
Distance from Copper Cliff (km)	4.3	5.0	11	13
Drainage area (A_d in ha)	76	250	460	340
Lake area (A_o in ha)	27.3	28.2	40.5	76.5
Lake volume (V in 10^5 m^3)	10.8	17.5	25.0	64.2
Mean depth (Z_{mean} in m)	4.0	6.2	6.2	8.3
Maximum depth (Z_{max} in m)	8.5	15.0	19.5	21.5
Shoreline length (L in km)	2.70	3.20	4.47	4.97

* from Cox (1978)

Table 2: Summary of treatments of the four study lakes.

Annual schedule of base and nutrient additions to Middle, Hannah and Lohi lakes. P was added as diluted liquid H_3PO_4, and quantities are taken from Yan and Lafrance (1982). Amounts indicated are in kg of P added with areal load during the treatment period ($mg/m^2/d$) in parentheses. Quantities of bulk dry $Ca(OH)_2$ and $CaCO_3$ added are in tonnes, with the calculated volumetric ANC load ($\mu eq.L^{-1}$) also shown. Values are taken from Table 6.1 in Yan and Dillon (1982).

Year	additive	Middle	Hannah	Lohi
1973	$Ca(OH)_2$	20.0		18.2
	$CaCO_3$	13.6		
	ANC	477		196
1974	$Ca(OH)_2$			4.1
	$CaCO_3$			
	ANC			45
1975	$Ca(OH)_2$		13	5
	$CaCO_3$		7.5	15
	ANC		477	184
	P	32.3 (1.24)		
1976	P	47.9 (1.15)	35.4 (0.89)	
1977	P	34.1 (2.52)	15.2 (1.14)	
1978	P	53.9 (2.25)	36.4 (1.47)	

Table 3: Major ion contents ($\mu eq.L^{-1}$) of Clearwater, Lohi, Middle and Hannah[1] lakes in 1973 in comparison with 40 lakes in the Experimental Lakes Area (data from Yan and Miller, 1982, Tables 1-2 and 1-3)

	Clearwater	Lohi	Middle	Hannah	ELA
Conductivity (μS)	89	88	131	166	19
H^+	51	41	40	51	<1
Ca^{2+}	315	310	490	570	80
Mg^{2+}	156	205	410	295	74
Na^+	61	83	104	152	39
K^+	33	33	49	54	10
Σ cations	616	672	1090	1120	203
SO_4^{2-}	579	556	927	1200	63
Cl^-	31[2]	34.5[2]	42.3[2]	76	39
NO_3^-	8	6	32	41	<1
HCO_3^-	0	0	0	0.2	62
Σ anions	618	596	1001	1320	164

[1]1974 data for Hannah Lake

[2]1974 data as 1973 data were not available. As both Na and Cl levels rose over time in the lake, we suspect that 1973 levels would have been a bit lower.

Table 4: Changes in average water chemistry in Clearwater Lake from 1973 to 2001

4a. Clearwater Lake Cations: Ca, Mg, Na and K as ($mg \cdot L^{-1}$)

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Ca	6.30	5.50	5.48	5.90	5.69	5.72	6.08	6.09	5.90	5.80	5.97	5.62	5.47	5.66	
n	8	23	21	21	11	10	15	9	6	7	7	9	7	7	
max	7.00	6.00	6.00	7.00	6.20	6.00	6.60	6.70	6.20	6.00	6.20	5.84	5.86	5.83	
min	6.00	5.00	5.00	5.00	5.20	5.40	5.33	5.60	5.40	5.50	5.40	5.31	5.13	5.41	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ca	5.96	6.01	6.22	5.93	5.85	5.50	5.22	5.19	4.55	4.39	4.30	4.41	4.37	4.24	4.09
n	7	8	5	7	7	2	5	6	6	5	4	6	6	5	6
max	6.13	6.20	6.40	6.05	6.02	5.52	5.35	5.55	4.66	4.48	4.40	4.55	4.50	4.30	4.20
min	5.80	5.60	6.00	5.77	5.71	5.49	5.13	4.82	4.32	4.28	4.12	4.30	4.15	4.20	4.00
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Mg	1.90	1.30	1.05	1.67	1.47	1.44	1.31	1.39	1.43	1.38	1.31	1.34	1.25	1.29	
n	8	24	21	21	11	10	15	8	6	7	7	8	6	7	
max	3.00	2.00	2.00	2.00	1.55	1.80	1.45	1.50	1.54	1.44	1.50	1.43	1.32	1.33	
min	1.00	1.00	1.00	1.00	1.40	1.35	1.20	1.25	1.35	1.32	1.22	1.30	1.20	1.26	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mg	1.34	1.41	1.38	1.35	1.30	1.25	1.18	1.23	1.07	1.10	1.05	1.06	1.06	1.08	1.09
n	9	8	5	7	7	2	5	6	6	5	4	6	6	5	6
max	1.42	1.48	1.41	1.38	1.33	1.26	1.21	1.46	1.10	1.20	1.07	1.08	1.08	1.10	1.12
min	1.26	1.34	1.35	1.28	1.27	1.24	1.16	1.13	1.05	1.06	1.01	1.04	1.04	1.06	1.06
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Na	1.40	1.50	1.62	1.53	1.61	1.61	1.62	1.86	2.02	2.05	2.14	2.26	2.32	2.43	
n	8	24	13	6	11	15	15	9	6	7	7	9	6	7	
max	2.00	2.00	2.00	1.60	1.70	1.70	1.90	2.40	2.40	2.15	2.25	2.30	2.42	2.49	
min	1.00	1.00	1.30	1.40	1.50	1.50	1.49	1.59	1.90	2.00	2.05	2.23	2.23	2.34	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Na	2.63	2.84	3.01	3.20	3.26	3.30	3.13	3.10	2.98	3.15	3.11	3.33	3.32	3.33	3.59
n	9	8	5	7	7	2	5	6	6	5	4	6	6	5	6
max	2.78	2.92	3.05	3.30	3.40	3.46	3.21	3.18	3.10	3.24	3.17	3.60	3.36	3.42	3.64
min	2.54	2.72	2.96	3.11	3.14	3.14	3.07	2.92	2.84	3.10	3.03	3.22	3.28	3.26	3.52
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
K	1.30	1.00	0.73	0.72	0.72	0.66	0.70	0.68	0.63	0.62	0.59	0.64	0.54	0.56	
n	8	24	12	6	11	15	14	9	6	7	7	9	7	7	
max	2.50	1.30	0.85	0.75	0.75	0.75	0.76	0.83	0.65	0.64	0.64	1.17	0.59	0.59	
min	0.90	0.70	0.60	0.70	0.70	0.25	0.60	0.60	0.60	0.60	0.56	0.56	0.49	0.53	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
K	0.61	0.60	0.62	0.64	0.64	0.63	0.59	0.55	0.60	0.58	0.56	0.59	0.58	0.58	0.60
n	9	8	5	7	7	2	5	5	6	5	4	6	6	5	6
max	0.81	0.63	0.65	0.66	0.65	0.65	0.62	0.62	0.71	0.71	0.57	0.60	0.60	0.60	0.63
min	0.57	0.57	0.59	0.63	0.63	0.61	0.53	0.39	0.54	0.49	0.55	0.57	0.57	0.57	0.58

Table 4b. Clearwater Lake anions: SO_4, Cl and Gran and fixed endpoint alkalinity as ($mg \cdot L^{-1}$)

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
SO_4	27.80	25.60	24.90	26.00	26.40	23.90	22.00	21.58	19.63	19.01	18.57	17.70	16.14	15.93	
n	17	24	13	20	11	12	6	10	6	7	7	9	6	6	
max	30.00	29.00	28.00	31.00	28.00	26.00	23.00	23.50	21.00	19.80	19.31	18.93	17.40	16.60	
min	26.00	20.00	21.00	23.00	25.00	23.00	21.00	20.00	16.00	18.10	17.63	15.93	15.05	14.80	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SO_4	16.09	17.03	16.34	16.29	14.96	14.38	13.04	12.64	11.17	11.08	10.75	10.30	10.83	9.90	10.67
n	9	7	4	7	7	2	5	6	6	5	4	6	6	5	6
max	17.60	17.60	16.85	17.55	15.65	14.45	14.20	15.10	11.30	13.00	11.80	11.00	11.00	9.00	11.50
min	13.70	16.60	16.05	15.45	13.90	14.30	11.80	11.60	11.10	10.50	10.30	9.00	10.50	10.50	10.00
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Cl		1.10	1.47	1.77	2.19	3.06	3.55	4.51	5.44	5.82	6.43	7.03	7.21	7.84	
n		22	13	3	11	15	14	9	6	6	6	9	7	7	
max		1.70	1.70	1.80	2.60	3.50	3.75	4.90	5.75	6.00	6.86	7.17	7.55	8.15	
min		0.80	1.30	1.70	2.05	2.80	3.38	4.20	4.90	5.55	5.70	6.78	6.99	7.60	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cl	8.19	8.76	8.96	9.16	9.43	9.20	9.00	7.80	8.14	7.85	7.66	8.47	8.07	7.80	8.13
n	9	8	5	7	7	2	5	6	6	5	4	6	6	5	6
max	8.40	9.20	9.20	9.50	10.00	9.30	9.70	9.41	8.34	8.14	7.84	10.40	8.60	7.80	8.40
min	7.65	8.10	8.50	8.80	9.00	9.10	8.50	2.89	7.94	7.72	7.43	7.80	7.80	7.60	7.80
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Alkt (pH 4.5)	<0	<0	<0	<0	<0	<0	<0	0.37			0.58	0.50	0.64	0.63	
n	14	23	21	22	13	16	5	3			2	7	7	7	
max								0.54			0.62	0.71	0.89	0.81	
min								0.20			0.53	0.36	0.45	0.54	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alkt (pH 4.5)	0.71	0.45	0.73	0.73	1.14	1.10	1.31	1.44	1.97	1.94	2.22	2.10	2.17	2.60	2.83
n	9	8	5	6	7	2	5	6	6	5	4	6	6	5	6
max	0.80	0.70	0.89	0.95	1.24	1.28	1.53	1.87	2.05	2.30	2.30	2.40	2.50	3.00	3.50
min	0.60	0.20	0.59	0.49	1.01	0.93	1.21	1.22	1.91	1.60	2.15	1.80	2.00	2.50	2.50
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Alkti as $CaCO_3$	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-1.78	-1.96	-1.67	-1.40	-1.27	-1.09	-1.11	
n								3	6	7	6	9	7	7	
max								-1.45	-1.72	-1.56	-1.21	-1.03	-0.87	-1.00	
min								-2.28	-2.14	-1.83	-1.50	-1.46	-1.31	-1.20	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alkti as $CaCO_3$	-1.11	-1.20	-1.03	-0.93	-0.71	-0.52	-0.47	-0.10	0.30	0.35	0.39	0.72	0.69	0.86	1.47
n	9	8	5	5	7	2	5	6	6	5	4	5	6	6	6
max	-0.96	-0.96	-0.95	-0.76	-0.60	-0.30	-0.44	0.23	0.36	0.45	0.53	0.87	0.83	1.05	2.65
min	-1.30	-1.30	-1.20	-1.10	-0.86	-0.75	-0.50	-0.29	0.23	0.28	0.15	0.62	0.499	0.69	0.68

Table 4c. Clearwater Lake sum of equivalent concentrations of cations and anions plus conductivity

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Cations ($\mu Eq \cdot L^{-1}$)	575.3		480.9	579.0	550.5	511.4	532.2	521.7	553.5	539.3	548.5	530.9	516.6	529.6	
n	8		13	5	11	10	6	4	6	6	6	8	6	5	
max	727.1		578.4	607.7	600.7	563.0	561.2	544.3	586.0	554.7	567.4	544.0	531.3	536.9	
min	470.0		428.1	553.7	506.9	472.6	488.1	502.2	524.7	520.2	527.8	513.7	487.3	520.2	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cations ($\mu Eq \cdot L^{-1}$)	559.6	578.8	588.7	583.3	570.4	550.1	519.7	514.1	435.8	468.9	449.5	468.6	465.3	460.8	467.2
n	7	6	4	6	7	2	5	6	6	5	4	5	6	4	5
max	579.9	601.1	594.0	593.9	582.5	558.2	529.0	552.2	471.8	482.4	458.1	475.0	473.0	465.0	470.0
min	546.4	561.2	576.0	567.2	555.7	542.0	512.3	476.8	306.0	458.8	439.1	461.0	463.0	455.0	464.0
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Anions ($\mu Eq \cdot L^{-1}$)			560.3	594.6	611.7	582.1	562.2	572.3	562.5	533.5	544.3	568.0	541.3	557.7	
n			13	3	11	12	5	4	6	6	6	8	6	5	
max			630.8	612.9	645.0	618.3	574.2	606.6	599.8	574.5	589.8	597.8	571.4	568.9	
min			476.7	578.8	578.3	560.6	544.9	551.7	488.4	381.5	385.2	533.3	521.9	534.3	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Anions ($\mu Eq \cdot L^{-1}$)	576.2	604.2	594.8	601.8	580.8	562.4	529.0	487.9	467.2	458.0	445.2	496.5	499.2	485.2	512.2
n	7	6	4	6	7	2	5	6	6	5	4	6	6	5	6
max	604.1	618.9	602.7	636.8	608.0	564.0	573.1	565.1	471.4	496.6	470.1	558.0	509.0	497.0	522.0
min	542.8	577.4	577.4	579.0	557.8	560.7	500.1	339.8	463.8	443.2	427.1	449.0	485.0	468.0	495.0
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
COND25 ($\mu S \cdot cm^{-1}$)	89.2	86.3	85.4	87.0	89.0	83.2	82.5	79.1	84.0	81.7	76.7	76.1	74.1	75.2	
n	5	23	21	20	11	15	14	8	6	7	7	9	7	6	
max	92.0	89.0	92.0	93.0	92.0	90.0	88.0	81.9	88.0	84.0	79.2	77.0	75.3	76.3	
min	86.0	84.0	78.0	78.0	84.5	76.0	80.0	75.0	82.0	80.0	70.0	71.5	72.1	72.4	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
COND25 ($\mu S \cdot cm^{-1}$)	77.0	80.8	81.2	80.7	75.8	74.5	68.4	65.6	61.5	59.6	58.2	59.5	60.5	59.4	62.2
n	9	8	5	7	7	2	5	6	6	5	4	6	6	5	6
max	79.4	81.7	82.6	82.7	77.1	74.6	70.0	66.8	63.5	60.0	59.0	61.0	63.0	61.0	65.0
min	74.3	79.3	79.6	79.0	74.2	74.4	67.3	64.6	59.4	59.4	57.6	58.0	59.0	58.0	59.0

Table 4d Clearwater Lake pH and Dissolved Inorganic Carbon (DIC)

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
pH	4.29	4.24	4.33	4.24	4.11	4.41	4.46	4.48	4.44	4.49	4.57	4.61	4.68	4.69	
n	16	23	21	20	11	16	15	8	6	7	7	9	7	7	
max	4.50	4.40	4.50	4.40	4.20	4.50	4.66	4.72	4.50	4.55	4.64	4.69	4.76	4.73	
min	4.10	4.10	4.20	4.10	3.95	4.30	4.30	4.33	4.37	4.37	4.51	4.57	4.62	4.66	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
pH	4.71	4.63	4.71	4.73	4.91	4.98	5.05	5.31	5.67	5.75	5.86	5.95	6.10	6.27	6.38
n	9	8	5	6	7	2	5	6	6	5	4	6	6	5	6
max	4.74	4.69	4.75	4.79	4.95	5.05	5.13	5.58	5.76	5.83	5.96	6.02	6.37	6.38	6.57
min	4.69	4.56	4.68	4.67	4.88	4.90	4.98	5.19	5.57	5.58	5.77	5.89	6.02	6.21	6.20
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
DIC ($mg \cdot L^{-1}$)							0.20		0.23	0.19	0.18	0.20	0.21	0.20	
n							12		6	7	6	9	7	6	
max							0.50		0.40	0.40	0.22	0.28	0.25	0.24	
min							0.20		0.20	0.01	0.13	0.10	0.18	0.16	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DIC ($mg \cdot L^{-1}$)	0.24	0.20	0.24	0.29	0.20	0.24	0.26	0.29	0.37	0.35	0.27	0.43	0.57	0.52	0.40
n	9	7	4	7	7	2	5	6	6	5	4	7	6	5	6
max	0.47	0.32	0.30	0.48	0.35	0.29	0.28	0.41	0.44	0.46	0.38	0.80	1.00	0.80	0.80
min	0.17	0.13	0.18	0.22	0.10	0.19	0.23	0.19	0.24	0.22	0.18	0.20	0.20	0.20	0.20

Table 4e Clearwater Lake nutrients: TP, NH_4-N, NO_3-N, TKN as ($\mu g \cdot L^{-1}$) and SiO_3 as ($mg \cdot L^{-1}$)

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
TP	5.9	5.5	4.1	4.5	6.5	4.6	2.5	3.5	2.3	2.9	3.4	3.0	3.0	2.6	
n	17	22	14	18	9	14	15	9	6	7	7	9	6	7	
max	10.0	12.0	12.0	9.6	10.0	9.0	3.9	5.6	3.9	4.6	4.9	3.8	3.5	3.3	
min	1.0	1.0	1.0	0.1	2.0	1.0	2.0	2.5	1.7	1.5	2.2	2.4	2.5	1.7	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TP	3.0	4.5	4.5	3.5	2.2	2.7	2.6	3.1	4.4	3.4	2.8	5.0	4.3	3.2	5.2
n	9	8	5	7	7	2	5	6	6	5	5	6	6	5	5
max	3.9	6.3	6.1	4.5	4.6	2.8	3.5	3.8	6.6	6.4	3.6	8.0	8.0	6.0	8.0
min	1.3	2.0	3.7	3.0	0.8	2.6	1.0	1.0	3.0	1.2	0.5	2.0	2.0	2.0	4.0
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
NH_4^+-N	35.0	14.8	20.7	25.7	36.2	33.5	24.5	18.9	7.0	9.6	14.0	7.1	12.6	18.0	
n	14	23	15	18	9	13	15	9	6	7	7	9	7	7	
max	100.0	30.0	50.0	40.0	60.0	76.0	48.0	34.9	17.0	28.0	40.0	13.0	22.0	41.0	
min	10.0	10.0	0.5	3.0	15.0	8.0	4.0	6.0	2.0	1.0	2.0	1.0	3.0	9.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NH_4^+-N	20.4	13.9	16.2	14.3	15.3	37.0	20.6	24.7	18.5	27.0	22.0	8.0	7.7	16.8	19.0
n	9	8	5	7	7	2	5	6	6	5	4	6	6	5	6
max	35.0	31.0	33.0	31.0	22.0	52.0	23.0	43.0	34.0	57.0	42.0	12.0	10.0	28.0	34.0
min	4.0	6.0	11.0	4.0	9.0	22.0	16.0	7.0	7.0	13.0	8.0	2.0	6.0	2.0	12.0
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
NO_3^--N	108.0	65.4	64.0	53.3	61.6	86.0	60.4	62.3	62.5	52.3	35.4	16.1	25.0	32.1	
n	16	21	10	13	8	12	15	9	6	7	7	9	7	7	
max	162.0	151.0	91.0	126.0	80.0	105.0	85.0	80.0	75.0	85.0	50.0	30.0	40.0	40.0	
min	81.0	41.0	41.0	19.0	45.0	75.0	35.5	13.9	55.0	20.0	20.0	5.0	12.0	25.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NO_3^--N	30.6	19.8	33.6	15.0	7.8	43.0	49.0	23.8	16.7	42.0	36.5	10.0	8.7	13.4	30.0
n	9	8	5	7	6	2	5	6	6	5	4	6	6	5	6
max	76.0	50.0	57.0	45.0	19.0	44.0	81.0	52.0	41.0	76.0	62.0	20.0	20.0	38.0	40.0
min	1.0	1.0	4.0	1.0	1.0	42.0	15.0	1.0	1.0	20.0	16.0	5.0	5.0	5.0	5.0

Table 4e Clearwater Lake cont'd nutrients: TKN, SiO_3

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
TKN	131.0	84.4	144.1	132.1	102.2	127.5	94.9	79.3	79.2	89.3	114.3	72.2	72.9	97.1	
n	16	23	15	21	10	12	23	9	6	7	7	9	7	7	
max	320.0	120.0	220.0	215.0	150.0	250.0	261.5	100.0	95.0	120.0	180.0	90.0	90.0	110.0	
min	50.0	50.0	80.0	35.0	60.0	60.0	7.1	60.0	55.0	80.0	70.0	40.0	50.0	80.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TKN	70.0	110.0	140.0	121.4	101.4	125.0	114.0	153.3	171.0	204.0	165.0	213.3	166.7	212.0	230.0
n	9	7	5	7	7	2	5	6	6	5	4	6	6	5	6
max	140.0	140.0	220.0	170.0	110.0	150.0	140.0	180.0	186.0	360.0	180.0	260.0	180.0	240.0	380.0
min	0.0	80.0	100.0	70.0	90.0	100.0	90.0	120.0	160.0	140.0	160.0	180.0	160.0	200.0	200.0
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
SiO_3	2.00	2.00	2.06	1.82	1.57	1.78	1.61	1.46	1.35	1.16	1.11	0.92	0.73	0.61	
n	15	24	13	5	11	8	15	8	6	7	7	9	7	7	
max	2.40	2.40	2.20	2.10	1.75	2.05	1.90	1.60	1.45	1.34	1.40	1.22	1.06	0.80	
min	0.90	1.70	1.90	1.65	1.40	1.60	1.45	1.32	1.30	1.03	0.86	0.71	0.50	0.46	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	0.54	0.71	0.96	0.69	0.44	0.57	0.60	0.68	0.72	0.96	0.98	0.99	1.07	1.02	1.15
n	9	8	5	7	7	2	5	6	6	5	4	6	6	5	6
max	0.74	0.82	1.14	0.92	0.78	0.78	0.74	0.88	0.84	1.02	1.12	1.08	1.18	1.16	1.22
min	0.42	0.58	0.70	0.44	0.20	0.36	0.52	0.52	0.64	0.92	0.88	0.92	0.96	0.92	1.06

Table 4f Clearwater Lake transparency and its determinants: Secchi depth, DOC, and total and acidified chlorophyll

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Secchi (m)	11.10	8.30	8.41	8.06	8.76	9.73	9.54	9.80	8.13	9.49	8.44	7.57	8.32	8.23	
n	17	24	21	22	11	15	15	7	6	7	7	9	6	7	
max	14.50	10.50	12.50	10.50	13.20	11.10	13.10	12.50	9.80	12.90	10.50	10.80	12.20	8.90	
min	5.80	5.50	6.00	4.50	6.50	7.20	7.50	8.50	7.00	6.30	6.80	6.10	7.00	7.30	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Secchi (m)	9.33	7.69	7.72	8.07	9.74	5.50	6.04	6.17	6.92	8.82	8.78	7.45	7.19	8.14	6.67
n	8	8	5	7	7	2	5	6	6	5	8	5	6	5	6
max	13.20	9.50	10.50	10.20	12.90	6.10	7.50	9.00	6.30	10.20	11.50	10.25	8.75	9.80	7.50
min	7.50	6.10	5.00	5.80	6.00	4.90	4.50	5.00	5.50	6.50	5.70	5.00	4.50	5.50	4.50
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
DOC ($mg \cdot L^{-1}$)									0.37	0.39	0.43	0.48	0.41	0.37	
n									6	7	7	9	7	7	
max									0.50	0.60	0.60	0.90	0.50	0.50	
min									0.20	0.20	0.30	0.20	0.30	0.20	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DOC ($mg \cdot L^{-1}$)	0.42	0.72	0.74	0.79	0.77	0.75	1.30	1.47	1.83	1.70	1.82	2.09	2.22	2.28	2.42
n	9	8	5	7	7	2	5	6	6	5	4	7	6	5	6
max	0.50	0.90	1.00	1.00	0.90	0.80	1.50	2.00	2.00	1.90	1.90	2.40	2.50	2.60	2.70
min	0.20	0.50	0.50	0.60	0.60	0.70	1.20	1.10	1.60	1.60	1.70	1.90	1.90	1.80	2.30
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Chlrat ($mg \cdot L^{-1}$)	1.30	0.52	1.04	0.78	0.64	0.70	0.81	0.60	0.52	0.67	0.82	0.80	0.73	0.60	
n	16	24	21	22	11	15	15	5	5	6	6	9	6	6	
max	3.20	1.30	2.40	1.80	1.20	1.10	1.50	0.80	0.60	1.00	1.10	1.50	1.30	0.80	
min	0.30	0.20	0.20	0.30	0.10	0.30	0.50	0.40	0.40	0.30	0.40	0.50	0.40	0.40	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chlrat ($mg \cdot L^{-1}$)	0.76	0.86	0.68	1.33	0.36	0.50	1.88	1.30	1.19	1.52	1.92	1.60	2.43	2.48	2.07
n	9	8	5	7	7	2	5	6	5	5	5	5	6	5	7
max	1.10	1.50	1.00	4.50	1.00	0.60	2.50	2.70	2.20	2.00	2.40	2.20	3.20	3.60	3.00
min	0.50	0.40	0.40	0.50	0.10	0.40	1.30	0.50	0.60	0.60	1.20	0.80	1.20	1.60	1.40
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Chlrac ($mg \cdot L^{-1}$)		0.31	0.81	0.41	0.33	0.49	0.43	0.26	0.36	0.40	0.42	0.53	0.32	0.38	
n		19	18	8	10	13	15	5	5	6	6	9	6	5	
max		0.70	2.30	1.00	1.10	0.80	1.20	0.30	0.40	0.70	0.80	1.00	0.80	0.50	
min		0.10	0.10	0.10	0.10	0.30	0.10	0.10	0.30	0.10	0.10	0.10	0.10	0.10	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chlrac ($mg \cdot L^{-1}$)	0.27	0.70	0.44	0.47	0.15	0.65	0.90	1.10	1.00	1.00	1.40	1.20	1.50	2.00	1.30
n	9	8	5	7	6	2	5	6	5	4	5	5	6	5	6
max	0.70	1.40	0.60	1.20	0.20	1.00	1.30	1.60	1.00	1.00	2.00	2.00	2.00	3.00	2.00
min	0.10	0.30	0.30	0.20	0.10	0.30	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 4g Clearwater Lake changes in total metal concentrations: Cu, Ni, Zn, Mn, Fe and Al as ($\mu g \bullet L^{-1}$)

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Cu	98.3	101.0	100.0	91.4	81.3	74.4	59.8	60.8	52.0	55.7	49.0		42.2	41.2	
n	9	12	14	13	11	14	5	9	3	3	2		6	6	
max	110.0	130.0	120.0	110.0	100.0	81.0	74.0	85.0	60.0	59.0	49.0		51.0	45.0	
min	90.0	80.0	70.0	74.0	51.0	68.0	52.0	48.0	38.0	52.0	49.0		20.0	37.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cu	42.8	45.8	41.7	34.5	21.4		24.7	20.0	11.2	8.7	8.6	9.0	8.6	7.4	8.1
n	7	8	3	2	4		3	6	4	5	4	6	6	5	6
max	46.0	61.0	44.0	35.0	36.0		28.0	23.0	13.0	9.0	9.4	10.6	8.9	8.2	8.7
min	39.0	39.0	40.0	34.0	15.5		21.0	16.0	9.8	8.3	7.7	8.3	7.0	6.5	7.3
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Ni	283.0	289.0	272.0	271.0	278.0	257.0	220.0	223.5	230.0	198.7	225.5		181.7	173.3	
n	10	13	14	13	11	14	5	9	3	3	2		6	6	
max	300.0	330.0	310.0	330.0	300.0	280.0	250.0	250.0	270.0	210.0	260.0		210.0	180.0	
min	240.0	270.0	250.0	250.0	220.0	230.0	210.0	190.0	170.0	180.0	191.0		160.0	160.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ni	176.2	180.0	176.7	150.0	91.0		123.3	115.0	86.2	75.5	77.9	78.0	77.8	69.0	70.8
n	8	8	3	2	4		3	6	4	5	4	6	6	5	6
max	200.0	200.0	180.0	150.0	150.0		130.0	120.0	94.0	78.0	81.4	84.5	87.1	72.2	73.2
min	150.0	150.0	170.0	150.0	70.0		120.0	100.0	79.0	69.0	74.2	73.9	69.4	65.1	66.9
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Zn	47.9	46.7	49.0	54.9	39.2	37.3	31.4	33.6	39.3	35.4	24.5	22.5	20.7	25.4	
n	11	13	13	13	11	14	5	8	3	7	6	6	6	7	
max	80.0	61.0	79.0	100.0	60.0	42.0	36.0	37.3	46.0	72.0	40.0	28.0	25.0	31.0	
min	30.0	36.0	39.0	40.0	28.0	34.0	27.0	30.0	31.0	13.0	14.0	14.0	16.0	23.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Zn	26.2	37.0	47.3	22.5	15.2		18.1	26.0	19.8	20.3	20.0	12.2	10.8	10.0	10.1
n	8	7	3	2	4		4	6	4	5	4	6	6	5	6
max	50.0	75.0	75.0	23.0	26.0		19.0	37.0	36.0	42.0	36.6	14.5	13.0	11.1	11.2
min	14.0	25.0	24.0	22.0	10.0		17.0	18.0	13.0	12.0	13.6	10.2	9.3	9.2	8.7
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Mn	328.0	310.0	288.6	301.2	290.0	297.0	277.6	269.2	274.8	282.8	245.7	252.3	252.9	236.7	
n	10	12	14	8	10	15	14	9	6	7	7	9	7	6	
max	360.0	412.0	310.0	320.0	310.0	315.0	290.0	294.6	284.0	300.5	270.0	266.0	320.0	260.0	
min	310.0	280.0	270.0	260.0	250.0	280.0	269.7	240.0	260.0	270.0	225.0	245.0	200.0	210.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mn	266.7	275.0	271.6	264.3	255.0	236.0	193.2	167.0	118.3	85.7	73.0	53.1	40.4	36.4	39.1
n	9	8	5	7	6	2	5	6	6	5	4	5	6	5	6
max	310.0	300.0	280.0	270.0	270.0	246.0	216.0	179.0	138.0	93.0	78.0	62.2	48.5	38.3	44.8
min	250.0	240.0	260.0	250.0	240.0	226.0	157.0	154.0	100.0	80.0	68.0	48.9	36.1	34.3	37.4

Table 4g Clearwater Lake cont'd. Changes in total metal concentrations: Mn, Fe and Al as ($\mu g \cdot L^{-1}$)

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Fe	114.0	93.9	131.9	90.8	88.2	78.0	53.0	58.4	50.0	39.4	53.6	86.1	70.1	57.6	
n	10	13	14	9	11	15	14	9	6	7	7	9	7	7	
max	200.0	180.0	250.0	150.0	130.0	370.0	70.0	85.2	70.0	50.0	80.0	145.0	115.0	80.0	
min	30.0	6.0	85.0	30.0	41.0	40.0	40.0	40.0	30.0	25.0	30.0	60.0	28.0	34.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Fe	52.8	49.5	82.1	71.7	35.0	76.0	50.0	78.8	43.8	29.6	38.0	34.8	51.4	72.4	48.4
n	9	8	5	7	6	2	5	6	6	5	4	6	6	5	6
max	110.0	66.0	110.0	95.0	53.0	116.0	89.0	212.0	91.0	50.0	60.0	84.8	139.0	163.0	83.2
min	10.0	34.0	60.0	52.0	15.0	36.0	21.0	26.0	10.0	16.0	24.0	11.6	16.1	23.3	20.7
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	
Al	420.0	516.0	446.7	397.1	381.0	324.3	277.6	275.0	233.3	175.6	220.9	177.4	141.8	133.0	
n	1	12	15	7	10	14	14	7	3	7	7	9	6	6	
max		790.0	510.0	460.0	420.0	380.0	362.0	289.4	250.0	269.0	281.0	239.0	179.0	165.0	
min		290.0	370.0	320.0	330.0	280.0	230.0	250.0	210.0	90.0	153.0	130.0	107.0	109.0	
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Al	126.3	141.6	173.0	130.8	120.0	90.5	79.4	56.2	20.5	25.8	30.5	17.4	15.1	15.8	19.9
n	9	7	2	5	4	2	5	6	6	5	4	5	6	5	6
max	158.0	194.0	191.0	154.0	140.0	101.0	100.0	69.0	38.0	30.0	58.0	25.4	28.3	22.1	28.0
min	97.0	107.0	155.0	110.0	93.0	80.0	70.0	41.0	4.0	21.0	16.0	11.8	8.0	10.5	14.9

Table 5. Changes in average water chemistry in Lohi Lake from 1973 to 2001

5a Lohi Lake cations: Ca, Mg, Na and K as ($mg \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Ca	6.20	9.00	7.90	8.60	7.96	7.18	6.75	6.29	5.99	5.88	5.77	5.81	5.97	5.55	5.96
n	13	3	24	21	22	12	15	12	8	6	7	7	9	7	7
max	7.00		8.40	10.00	8.00	8.60	7.20	6.99	6.56	6.20	6.00	6.20	6.65	6.14	6.15
min	6.00		7.60	6.80	7.00	6.60	6.40	5.77	5.60	5.40	5.60	5.30	5.72	4.50	5.47
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ca	6.25	6.08	6.32	6.09	5.82	5.38	5.21	5.31	4.62	4.31	4.26	4.18	4.36	4.33	4.12
n	7	8	5	7	7	2	5	5	5	5	5	4	6	5	6
max	6.46	6.40	6.55	6.23	6.01	5.39	5.37	5.61	4.72	4.40	4.36	4.40	4.45	4.44	4.20
min	6.10	5.60	6.00	5.94	5.63	5.37	5.05	4.90	4.52	4.16	4.10	3.90	4.10	4.20	4.00

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mg	2.50	1.30	1.30	1.09	1.23	1.57	1.56	1.40	1.40	1.52	1.49	1.40	1.49	1.42	1.49
n	13	3	23	22	22	12	15	12	8	6	7	7	9	6	7
max	2.00	2.00	4.00	2.00	2.00	1.85	2.00	1.50	1.60	1.60	1.58	1.52	1.60	1.49	1.56
min	1.00	1.00	1.00	1.00	1.00	1.50	1.45	1.30	1.25	1.45	1.42	1.34	1.36	1.32	1.39
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mg	1.59	1.64	1.59	1.58	1.51	1.43	1.37	1.45	1.23	1.29	1.23	1.21	1.26	1.28	1.27
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	1.64	1.68	1.62	1.62	1.56	1.44	1.41	1.72	1.25	1.41	1.25	1.24	1.32	1.30	1.30
min	1.50	1.56	1.53	1.50	1.48	1.42	1.32	1.35	1.20	1.23	1.18	1.16	1.24	1.26	1.24

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Na	1.90	1.70	1.50	1.68	1.58	1.63	1.73	1.70	1.95	2.03	2.09	2.11	2.32	2.44	2.58
n	13	3	24	13	5	12	28	25	8	6	7	7	9	6	7
max	3.00	2.00	2.00	2.10	1.60	1.80	1.80	2.00	2.56	2.20	2.25	2.30	2.44	2.62	2.68
min	1.00	1.00	1.00	1.40	1.50	1.50	1.50	1.30	1.65	1.90	2.00	2.00	2.16	2.32	2.48
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Na	2.91	3.15	3.25	3.51	3.59	3.66	3.56	3.65	3.52	3.71	3.78	3.89	4.08	4.15	4.64
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	3.02	3.29	3.30	3.59	3.80	3.72	3.67	3.83	3.68	3.80	3.84	3.98	4.16	4.24	4.88
min	2.82	2.94	3.16	3.46	3.49	3.60	3.49	3.55	3.40	3.62	3.66	3.80	4.00	4.06	4.52

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
K	1.30	1.10	1.00	0.78	0.75	0.76	0.70	0.76	0.70	0.68	0.66	0.64	0.64	0.61	0.62
n	13	3	24	13	5	12	15	12	8	6	7	7	8	7	7
max	2.30	1.20	1.30	0.94	0.80	0.80	0.80	0.95	0.75	0.70	0.70	0.66	0.66	0.69	0.65
min	1.00	1.00	0.80	0.65	0.73	0.70	0.15	0.65	0.65	0.64	0.64	0.60	0.63	0.54	0.59
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
K	0.71	0.70	0.73	0.77	0.77	0.75	0.73	0.74	0.74	0.80	0.74	0.75	0.77	0.77	0.76
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	0.92	0.74	0.74	0.80	0.78	0.76	0.75	0.83	0.78	0.82	0.76	0.76	0.80	0.78	0.80
min	0.66	0.63	0.72	0.76	0.74	0.75	0.71	0.64	0.65	0.78	0.72	0.72	0.75	0.76	0.73

Table 5b Lohi Lake anions: SO_4, Cl and Gran and fixed endpoint alkalinity as ($mg \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SO_4	26.7	27.3	25.9	24.0	25.0	24.8	23.7	21.4		20.3	18.8	18.5	19.1	17.4	17.7
n	14	3	24	14	20	12	28	9		5	7	7	9	6	6
max	29.0	29.0	29.0	27.0	29.0	26.0	30.0	23.0		21.0	19.6	20.1	20.4	19.2	18.5
min	24.0	25.0	23.0	20.0	23.0	24.0	20.0	20.0		19.0	18.2	17.4	17.9	16.0	16.8
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	18.7	19.0	18.0	18.3	16.2	15.2	13.5	12.9	11.0	10.4	10.5	10.4	11.2	11.0	10.8
n	9	8	3	7	7	2	5	6	5	5	5	4	6	5	6
max	20.8	20.4	18.2	19.8	16.8	15.4	14.6	15.1	11.1	10.6	10.8	11.0	11.5	11.5	11.0
min	16.4	17.6	17.6	17.7	15.4	15.0	12.2	11.4	11.0	10.3	10.0	9.0	10.5	10.5	10.5
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cl			1.4	2.0	2.4	3.0	4.0	4.3	4.9	5.5	5.6	6.2	6.9	6.9	7.5
n			22	14	5	12	28	12	8	6	7	7	9	6	7
max			2.3	2.6	2.5	3.5	4.4	4.6	5.2	5.7	5.8	6.6	7.1	7.1	7.8
min			1.3	1.7	2.3	2.6	3.7	4.1	4.6	5.2	5.3	5.4	6.8	6.6	7.1
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cl	8.1	8.6	8.8	9.2	9.6	9.6	9.3	8.2	8.8	8.5	8.4	8.4	8.9	8.8	9.7
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	8.5	9.0	9.1	9.7	10.0	9.6	9.5	9.3	9.0	8.7	8.9	8.6	9.0	9.0	10.0
min	7.4	7.7	8.5	8.8	9.2	9.6	9.1	2.9	8.7	8.3	8.0	8.2	8.6	8.8	9.4
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Alkt (pH 4.5)	0.0	3.8	2.3	5.1	2.4	1.1	1.2	0.9	0.9	0.7	0.8	0.9	0.7	0.7	0.6
n	14	3	24	22	23	12	27	25	6	6	7	7	9	7	7
max		4.5	4.0	7.0	3.5	1.4	2.2	1.2	1.6	0.9	1.0	1.0	0.9	1.0	0.9
min		3.0	1.0	2.0	1.7	0.6	0.6	0.6	0.6	0.5	0.4	0.7	0.6	0.5	0.4
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alkt (pH 4.5)	0.6	0.5	0.7	0.7	1.3	1.3	1.8	2.2	3.1	3.1	3.3	3.3	3.1	3.6	3.8
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	0.8	0.7	0.8	0.9	1.5	1.4	2.1	2.8	3.2	3.7	3.4	4.2	4.0	4.0	4.0
min	0.5	0.4	0.5	0.3	1.2	1.3	1.6	1.6	3.0	2.7	3.2	3.0	2.0	3.0	3.5
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Alkti as $CaCO_3$									-1.15	-1.10	-0.99	-0.94	-1.00	-1.02	-1.15
n									3	6	7	7	9	7	7
max									-1.08	-0.85	-0.80	-0.85	-0.88	-0.78	-0.86
min									-1.21	-1.36	-1.07	-1.05	-1.13	-1.20	-1.30
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alkti as $CaCO_3$	-1.23	-1.15	-1.10	-1.24	-0.49	-0.33	-0.01	0.56	1.36	1.52	1.58	1.69	1.54	1.67	1.89
n	9	8	4	7	7	2	5	6	5	5	5	5	6	5	5
max	-1.10	-1.10	-0.91	-0.83	-0.32	-0.24	0.08	1.21	1.47	1.79	1.73	1.86	1.71	2.09	2.18
min	-1.40	-1.20	-1.30	-2.00	-0.66	-0.42	-0.10	0.11	1.24	1.35	1.26	1.51	1.27	1.39	1.62

Table 5c Lohi Lake sums of equivalent concentrations of cations and anions plus conductivity

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cations ($\mu Eq \cdot L^{-1}$)	624.1	623.5		586.1	544.1	556.7	329.3	323.5	284.3	549.2	539.2	538.7	556.2	537.2	566.5
n	13	3		12	5	12	30	3	4	5	7	6	9	6	6
max	760.3	692.9		675.5	545.3	622.8	352.9	333.3	294.1	564.1	564.0	561.5	601.3	570.1	580.3
min	459.7	567.0		508.1	540.7	522.6	313.7	313.7	274.5	517.2	517.9	521.6	535.7	477.5	531.8
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cations ($\mu Eq \cdot L^{-1}$)	610.7	616.6	630.1	627.5	600.6	573.9	549.9	562.7	472.1	510.2	502.0	496.5	519.7	523.2	533.6
n	7	8	3	7	7	2	5	5	5	5	5	4	6	4	5
max	620.5	638.4	637.4	637.0	621.6	577.1	564.2	597.3	513.8	523.6	521.8	513.0	531.0	525.0	546.0
min	599.8	583.6	621.5	618.0	584.9	570.7	537.1	533.4	336.7	492.6	479.7	480.0	503.0	522.0	527.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Anions ($\mu Eq \cdot L^{-1}$)				563.3	592.3	597.2	606.2	570.6	574.2	578.2	549.3	568.0	595.5	527.2	586.5
n				13	5	11	28	3	3	5	7	6	9	6	6
max				618.5	647.8	617.4	731.4	573.1	591.4	598.4	564.2	603.4	623.4	599.7	604.3
min				496.4	554.1	568.2	531.1	568.3	556.5	543.0	538.6	527.3	571.3	354.2	561.7
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Anions ($\mu Eq \cdot L^{-1}$)	628.1	640.4	627.3	644.6	609.3	591.6	549.3	511.2	498.4	479.9	477.5	522.5	545.2	550.6	575.7
n	7	8	3	7	7	2	5	6	5	5	5	4	6	5	6
max	667.9	673.3	640.0	680.7	627.7	596.1	580.9	592.8	501.2	489.0	496.3	533.0	573.0	557.0	587.0
min	607.9	603.7	620.9	620.1	596.5	587.1	521.5	357.2	492.7	467.5	465.4	508.0	527.0	542.0	564.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
COND25 ($\mu S \cdot cm^{-1}$)	87.5	76.3	75.2	78.9	76.8	76.7	77.6	78.4	76.3	76.7	77.0	75.5	78.7	76.5	79.4
n	13	4	24	22	22	13	24	27	8	6	7	7	9	7	6
max	101.0	78.0	77.0	84.0	82.0	81.0	80.0	80.0	79.5	80.0	78.0	77.7	86.6	79.4	81.3
min	81.0	74.0	73.0	71.0	75.0	74.0	74.0	75.0	73.9	68.0	76.0	74.0	76.7	73.1	76.7
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
COND25 ($\mu S \cdot cm^{-1}$)	83.1	85.3	85.7	86.6	78.7	76.5	70.5	69.2	65.6	62.8	62.4	64.0	66.7	66.0	69.0
n	9	8	5	7	7	2	5	6	5	4	5	5	6	5	6
max	86.7	87.7	89.0	88.3	79.9	76.6	71.2	72.5	66.6	63.2	63.4	64.3	68.0	67.0	71.0
min	77.7	82.8	83.4	85.7	77.5	76.4	69.8	67.6	64.0	62.0	61.6	63.6	65.0	65.0	66.0

Table 5d Lohi Lake pH and Dissolved Inorganic Carbon (DIC)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
pH	4.39	6.12	6.04	6.09	6.12	5.31	4.85	4.76	4.80	4.68	4.70	4.74	4.71	4.71	4.69
n	14	4	24	22	23	12	27	27	8	6	7	7	9	7	7
max	4.50	7.00	6.80	7.20	6.50	5.70	5.10	4.90	5.00	4.73	4.76	4.77	4.76	4.80	4.78
min	4.30	5.60	5.50	5.00	5.80	5.00	4.00	4.50	4.60	4.62	4.62	4.68	4.67	4.64	4.63
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
pH	4.68	4.64	4.71	4.70	5.02	5.17	5.51	5.92	6.21	6.28	6.33	6.29	6.39	6.49	6.57
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	4.72	4.69	4.75	4.76	5.14	5.19	5.72	6.26	6.24	6.33	6.48	6.43	6.53	6.56	6.65
min	4.63	4.60	4.67	4.59	4.94	5.15	5.35	5.64	6.16	6.24	6.18	6.15	6.32	6.42	6.49
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
DIC ($mg \cdot L^{-1}$)							0.56			0.37	0.24	0.20	0.20	0.20	0.37
n							2			6	7	6	9	7	7
max							1.10			0.80	0.40	0.23	0.29	0.24	1.42
min							0.01			0.20	0.16	0.16	0.12	0.15	0.16
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DIC ($mg \cdot L^{-1}$)	0.24	0.20	0.21	0.25	0.22	0.26	0.28	0.37	0.59	0.60	0.57	0.40	0.57	0.80	0.73
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	0.57	0.28	0.27	0.41	0.33	0.29	0.50	0.56	0.76	0.78	0.68	0.60	0.80	1.20	0.80
min	0.16	0.13	0.13	0.19	0.15	0.23	0.16	0.19	0.47	0.48	0.46	0.20	0.20	0.60	0.40

Table 5e Lohi Lake nutrients: TP, NH_4-N, NO_3-N, TKN, as ($\mu g \cdot L^{-1}$) and SiO_3 as ($mg \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
TP	6.1	3.7	5.0	3.7	5.4	7.3	5.4	4.1	3.6	3.6	3.3	4.1	4.0	2.9	2.9
n	12	3	20	16	22	9	26	27	7	6	7	7	9	7	6
max	12.0	5.0	14.0	8.0	9.0	10.0	10.0	12.2	4.2	4.9	4.6	6.2	5.2	3.7	3.5
min	2.0	3.0	1.0	1.0	1.0	3.5	1.0	2.5	2.7	2.4	2.2	3.5	3.2	1.6	2.2
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TP	2.7	3.4	3.7	2.7	3.2	3.5	3.6	5.3	7.3	5.9	5.5	6.5	5.3	3.2	6.8
n	9	6	5	7	7	2	5	6	5	5	5	4	6	5	5
max	4.1	4.6	5.1	3.4	5.8	3.8	4.8	8.2	10.7	10.0	6.2	12.0	12.0	4.0	10.0
min	1.2	1.8	1.5	1.6	1.6	3.2	1.4	3.8	5.6	2.3	3.5	4.0	2.0	2.0	4.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
NH_4^+-N	68.6	50.0	23.8	25.0	29.4	22.5	42.5	29.2	25.0	13.7	9.7	14.6	8.0	7.9	11.9
n	14	3	24	14	18	13	27	26	8	6	7	7	9	7	7
max	110.0	70.0	91.0	70.0	65.0	50.0	64.0	68.4	36.0	23.0	26.0	28.0	21.0	19.0	33.0
min	10.0	40.0	10.0	0.5	15.0	10.0	4.0	8.3	9.6	1.0	5.0	3.0	2.0	1.0	3.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NH_4^+-N	14.8	17.4	15.0	16.3	13.0	30.0	10.4	22.2	31.6	33.4	37.0	14.5	12.3	12.8	22.0
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	33.0	28.0	28.0	30.0	28.0	47.0	20.0	51.0	45.0	63.0	60.0	24.0	24.0	24.0	28.0
min	6.0	6.0	7.0	10.0	4.0	13.0	6.0	0.5	13.0	16.0	24.0	6.0	2.0	2.0	12.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
NO_3^--N	76.9	78.0	76.7	54.7	35.9	25.8	68.7	67.6	56.4	67.5	54.6	54.4	34.4	40.0	54.3
n	14	3	23	14	12	12	26	27	8	6	7	7	9	7	7
max	162.0	82.0	122.0	152.0	80.0	85.0	150.0	90.0	90.0	75.0	100.0	74.0	70.0	70.0	65.0
min	51.0	71.0	31.0	1.0	10.0	5.0	10.0	44.0	9.6	60.0	27.0	38.0	10.0	15.0	45.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NO_3^--N	55.7	59.9	59.6	41.6	15.8	33.5	13.4	17.0	12.0	5.6	14.0	8.8	6.0	8.6	14.3
n	9	8	5	7	6	2	5	6	5	5	5	4	6	5	6
max	83.0	95.0	94.0	78.0	44.0	60.0	47.0	51.0	39.0	12.0	56.0	10.0	11.0	21.0	26.0
min	28.0	26.0	11.0	14.0	1.0	7.0	1.0	1.0	2.0	2.0	2.0	5.0	5.0	5.0	5.0

Table 5e Lohi Lake cont'd nutrients TKN, ans SiO_3

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
TKN	193.0	113.0	145.0	180.2	196.5	150.0	179.6	108.3	123.4	113.3	104.3	102.9	95.6	81.4	80.0
n	13	3	24	15	20	11	25	44	8	6	7	7	9	7	7
max	300.0	130.0	200.0	310.0	330.0	190.0	500.0	220.0	215.5	150.0	120.0	120.0	120.0	100.0	100.0
min	110.0	100.0	70.0	110.0	140.0	110.0	30.0	15.0	82.7	90.0	90.0	80.0	80.0	60.0	60.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TKN	85.0	110.0	130.0	118.6	120.0	155.0	162.0	186.7	230.0	260.0	220.0	205.0	213.3	228.0	263.3
n	6	8	5	7	7	2	5	6	4	5	4	4	6	5	6
max	110.0	150.0	170.0	160.0	140.0	170.0	180.0	200.0	260.0	460.0	240.0	300.0	240.0	240.0	360.0
min	60.0	80.0	110.0	100.0	100.0	140.0	140.0	160.0	200.0	180.0	200.0	20.0	200.0	200.0	340.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SiO_3	1.30	1.20	1.60	2.19	2.22	2.17	2.17	1.30	1.04	1.06	0.87	1.02	0.76	0.61	0.53
n	13	3	24	13	5	12	8	15	7	6	7	7	9	7	7
max	1.40	1.30	2.30	2.50	2.30	2.25	2.45	1.90	1.25	1.35	1.20	1.30	1.11	0.97	0.74
min	1.10	1.20	1.40	1.90	2.10	2.10	1.90	0.75	0.85	0.85	0.67	0.78	0.51	0.43	0.38
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SiO_3	0.50	0.54	0.56	0.40	0.34	0.43	0.40	0.56	0.71	0.72	0.96	1.10	0.88	0.85	1.14
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	0.66	0.78	0.86	0.60	0.64	0.76	0.60	0.78	0.98	0.84	1.08	1.14	0.96	1.08	1.26
min	0.46	0.34	0.32	0.20	0.14	0.10	0.28	0.34	0.52	0.64	0.88	1.06	0.80	0.68	1.08

Table 5f Lohi Lake transparency and its determinants: Secchi depth, DOC and total and acidified chlorophyll

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Secchi (m)	8.8	16.4	5.6	5.6	5.7	6.9	9.3	7.6	8.8	6.5	7.8	7.9	4.8	6.7	6.5
n	14	3	24	20	22	12	28	27	8	6	7	7	9	6	7
max	12.0	17.0	12.0	9.0	7.5	9.7	12.0	10.1	11.0	8.0	10.0	9.4	6.0	8.0	8.0
min	7.0	16.0	4.0	2.8	3.5	5.5	5.6	4.5	5.5	5.1	6.8	6.0	1.5	5.8	5.2
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Secchi (m)	8.2	5.6	5.2	5.9	5.2	3.8	4.3	4.6	5.2	6.0	5.3	5.4	5.3	7.2	5.4
n	8	8	5	7	7	2	5	6	5	5	8	5	6	6	6
max	10.1	6.6	6.0	7.5	5.7	4.5	5.0	5.5	6.8	7.5	6.0	7.0	5.5	8.3	7.2
min	6.3	3.7	4.5	3.9	4.6	3.0	3.3	4.0	3.9	4.0	4.4	4.0	5.0	6.0	4.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
DOC ($mg \cdot L^{-1}$)						1.00	1.05			0.83	0.66	0.59	0.79	0.63	0.56
n						6	2			6	7	7	9	7	7
max						1.00	1.10			1.00	0.90	0.90	1.00	0.80	0.80
min						1.00	1.00			0.70	0.50	0.30	0.60	0.50	0.20
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DOC ($mg \cdot L^{-1}$)	0.51	0.82	1.02	0.89	1.27	1.35	2.00	2.07	2.32	2.20	2.34	2.65	2.63	2.52	2.80
n	9	8	5	7	7	2	5	6	5	5	5	4	6	5	6
max	0.60	1.10	1.20	1.20	1.60	1.40	2.40	2.70	2.40	2.40	2.50	2.80	2.70	2.90	3.00
min	0.40	0.70	0.90	0.70	1.00	1.30	1.90	1.50	2.20	2.10	2.10	2.50	2.20	2.20	2.50
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Chlrat ($mg \cdot L^{-1}$)	1.70	0.70	0.90	1.31	1.29	1.23	0.72	0.84	0.74	0.70	0.58	0.59	0.97	0.54	0.33
n	14	1	24	22	22	12	27	26	7	5	5	7	9	7	6
max	3.90		2.20	2.40	2.80	2.60	1.20	1.50	1.10	0.80	0.70	1.00	3.10	1.00	0.50
min	0.50		0.20	0.20	0.40	0.40	0.40	0.40	0.50	0.60	0.40	0.30	0.50	0.30	0.20
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chlrat ($mg \cdot L^{-1}$)	0.37	0.44	0.86	1.93	0.59	0.85	2.88	3.08	2.22	2.76	3.36	3.48	2.67	2.52	2.90
n	9	8	5	7	7	2	5	6	5	5	5	5	6	5	6
max	0.80	1.10	1.50	9.60	0.90	1.10	6.00	6.40	4.30	3.60	4.00	5.60	4.00	3.60	4.40
min	0.20	0.20	0.60	0.30	0.40	0.60	1.40	1.70	0.80	1.00	2.80	2.00	1.40	1.20	1.20
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Chlrac ($mg \cdot L^{-1}$)			0.57	0.83	0.88	0.53	0.51	0.52	0.33	0.48	0.38	0.45	0.64	0.24	0.14
n			21	20	6	11	24	25	7	5	6	6	9	7	5
max			1.50	1.80	1.70	1.10	1.20	1.20	0.90	0.60	0.50	0.80	2.30	0.70	0.20
min			0.10	0.10	0.50	0.10	0.20	0.10	0.10	0.30	0.20	0.20	0.10	0.10	0.10
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chlrac ($mg \cdot L^{-1}$)	0.11	0.29	0.42	0.41	0.18	0.80	1.44	1.60	1.43	1.50	2.20	1.40	1.67	1.60	2.00
n	9	8	5	7	6	2	5	6	5	4	5	5	6	5	6
max	0.20	0.60	1.00	1.60	0.30	1.30	3.40	3.70	3.17	2.00	3.00	3.00	3.00	2.00	3.00
min	0.10	0.10	0.10	0.10	0.10	0.30	0.10	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00

Table 5g Lohi Lake changes in total metal concentrations: Cu, Ni, Zn, Mn, Fe and Al as ($\mu g \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cu	83.6	19.0	43.7	43.1	37.3	43.9	70.5	64.3	68.1	69.0	63.3	57.5		74.2	80.0
n	8	3	14	16	12	11	29	9	8	3	3	2		6	6
max	110.0	36.0	80.0	66.0	60.0	70.0	83.0	88.0	73.0	77.0	67.0	58.0		99.0	89.0
min	60.0	10.0	27.0	26.0	16.0	20.0	60.0	41.0	62.0	61.0	60.0	57.0		36.0	68.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cu	91.4	82.8	77.3	67.3	31.0		28.7	16.0	10.5	10.4	10.0	11.2	11.0	9.4	11.2
n	8	8	3	3	4		3	6	4	5	5	4	6	5	6
max	100.0	94.0	85.0	80.0	52.0		55.0	19.0	12.0	12.0	10.6	12.7	12.5	10.8	12.8
min	83.0	74.0	73.0	61.0	21.0		13.0	12.0	10.0	9.4	9.3	10.2	9.6	7.4	9.3
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Ni	254.0	140.0	195.0	166.0	176.0	221.0	237.0	210.0	217.1	236.7	192.0	224.0		253.3	243.3
n	8	3	14	14	12	11	29	9	7	3	3	2		6	6
max	290.0	170.0	230.0	240.0	200.0	250.0	270.0	260.0	226.7	290.0	200.0	260.0		300.0	270.0
min	220.0	120.0	130.0	120.0	150.0	190.0	210.0	150.0	210.0	190.0	180.0	188.0		210.0	210.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ni	265.0	241.2	233.3	203.3	106.2		98.3	102.5	76.3	70.3	70.4	74.2	84.5	74.5	68.3
n	8	8	3	3	4		3	6	3	5	5	5	6	5	6
max	320.0	260.0	260.0	260.0	170.0		120.0	110.0	85.0	74.0	76.0	83.5	97.6	84.2	73.9
min	230.0	220.0	220.0	220.0	85.0		65.0	90.0	70.0	67.5	67.2	68.2	73.2	60.9	61.1
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Zn	41.6	21.3	32.3	28.1	38.0	33.1	32.4	29.1	31.0	35.7	32.5	24.2	27.2	27.0	34.6
n	7	3	14	15	12	12	16	8	8	3	6	6	6	7	7
max	70.0	25.0	50.0	65.0	90.0	50.0	38.0	34.0	35.3	42.0	45.0	38.0	32.0	34.0	39.0
min	27.0	19.0	19.0	18.0	20.0	25.0	25.0	21.0	25.0	29.0	27.0	13.0	21.0	20.0	31.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Zn	37.8	36.5	47.0	31.7	18.1		19.6	26.3	25.0	20.4	14.4	12.1	12.1	10.5	9.2
n	8	6	3	3	4		4	6	4	5	5	5	6	5	6
max	53.0	53.0	52.0	38.0	29.0		35.0	40.0	54.0	40.0	18.5	15.8	16.9	12.2	10.4
min	29.0	31.0	32.0	28.0	11.5		8.4	13.0	12.0	12.0	11.6	10.0	9.6	7.9	7.0

Table 5g Lohi Lake cont'd Changes in total metal concentrations: Mn, Fe and Al as ($\mu g \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mn	284.0	223.0	243.0	173.8	140.0	168.2	283.7	278.6	273.1	276.8	278.4	233.6	242.8	244.3	227.1
n	7	3	14	16	7	11	15	12	8	6	7	7	9	7	7
max	320.0	240.0	290.0	260.0	180.0	230.0	305.0	300.0	290.0	290.0	300.0	260.0	255.0	300.0	240.0
min	250.0	210.0	200.0	100.0	110.0	140.0	250.0	259.6	260.0	265.0	265.0	215.0	225.0	190.0	190.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mn	257.8	247.5	249.0	243.3	218.6	180.0	143.4	128.8	98.6	76.6	51.2	47.8	43.3	34.9	38.9
n	9	8	5	6	7	2	5	6	5	5	5	4	6	5	6
max	290.0	260.0	260.0	260.0	250.0	195.0	148.0	141.0	119.0	94.0	70.0	54.7	51.9	38.8	48.8
min	240.0	230.0	230.0	230.0	200.0	165.0	135.0	111.0	74.0	66.0	35.0	40.0	40.2	29.8	31.1
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Fe	90.0	36.0	51.2	113.9	92.6	72.0	53.3	48.2	44.2	55.0	38.2	41.6	71.1	53.0	53.1
n	8	3	14	16	8	12	15	12	8	6	6	7	9	7	7
max	120.0	50.0	750.0	190.0	160.0	100.0	100.0	147.0	60.0	70.0	45.0	55.0	105.0	95.0	73.0
min	27.0	8.0	30.0	57.0	30.0	34.0	10.0	31.3	23.7	40.0	25.0	30.0	50.0	32.0	45.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Fe	75.1	53.4	62.9	68.7	74.4	96.0	63.2	88.7	93.8	84.8	53.2	80.9	69.7	55.6	104.3
n	9	7	5	6	7	2	5	6	5	5	5	4	6	5	6
max	230.0	72.0	76.0	88.0	150.0	124.0	103.0	173.0	140.0	156.0	96.0	166.0	116.0	114.0	190.0
min	16.0	37.0	53.0	57.0	37.0	68.0	33.0	33.0	52.0	36.0	28.0	32.7	41.2	25.6	61.2
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Al			143.0	106.2	123.0	97.4	154.3	159.6	169.2	153.3	138.9	174.2	150.1	138.2	140.2
n			14	12	7	9	14	26	8	3	7	7	9	6	6
max			240.0	220.0	370.0	150.0	210.0	280.0	200.0	160.0	201.0	231.0	174.0	166.0	163.0
min			40.0	43.0	38.0	69.0	110.0	78.0	139.5	140.0	51.0	130.0	116.0	116.0	106.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Al	146.7	158.8	130.8	153.8	107.0	73.5	44.2	23.5	8.2	21.8	14.4	14.7	12.8	12.3	19.6
n	9	8	4	5	4	2	5	6	5	5	5	5	6	5	6
max	186.0	222.0	194.0	179.0	145.0	80.0	78.0	40.0	25.0	28.0	42.0	21.8	20.6	19.8	28.1
min	119.0	102.0	25.0	121.0	79.0	67.0	33.0	14.0	1.0	14.0	4.0	8.8	7.7	5.3	8.3

Table 6 Changes in average water chemistry in Middle Lake from 1973 to 2001

6a Middle Lake cations: Ca, Mg, Na and K as ($mg \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Ca	9.80	14.00	14.20	12.52	12.59	12.04	11.47	10.85	10.24	10.13	10.10	9.67	9.71	8.85	9.34
n	9	3	24	20	22	10	15	13	5	6	7	7	8	7	6
max	10.00	15.00	15.00	14.00	14.00	12.80	12.00	11.60	10.80	10.60	10.40	10.20	10.00	9.48	9.54
min	9.00	13.00	14.00	12.00	12.00	11.40	10.80	10.20	10.00	9.20	9.80	9.20	8.90	7.85	8.94
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ca	9.71	9.94	9.76	9.57	9.26	8.46	8.42	9.96	8.34	8.57	8.60	8.80	8.74	8.92	9.25
n	8	8	5	7	6	2	5	6	5	4	5	5	6	5	6
max	10.00	10.30	10.40	10.12	9.86	8.68	9.85	12.40	8.76	8.76	8.76	9.15	9.00	9.05	9.40
min	9.20	9.60	9.00	9.01	8.93	8.24	7.39	8.23	7.60	8.40	8.34	8.60	8.55	8.80	8.95
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mg	5.00	3.00	2.60	2.99	3.18	3.61	3.48	2.98	3.30	3.43	3.38	3.24	3.25	2.97	3.21
n	9	3	23	21	22	11	15	13	4	6	7	7	9	7	6
max	6.00		4.00	4.00	4.00	3.85	3.65	3.10	3.50	3.60	3.52	3.42	3.40	3.29	3.24
min	3.00		2.00	2.00	2.00	3.40	3.30	2.85	2.85	3.25	3.32	3.14	3.05	2.41	3.12
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mg	3.36	3.50	3.37	3.21	3.31	3.08	3.02	3.24	2.65	2.83	2.92	3.01	3.07	3.20	3.33
n	9	8	5	7	6	2	5	6	5	4	5	5	6	5	6
max	3.44	3.74	3.57	3.70	3.40	3.17	3.25	3.54	2.80	3.07	2.99	3.06	3.16	3.28	3.42
min	3.16	3.24	3.10	1.57	3.25	3.00	2.84	3.00	2.35	2.31	2.74	2.92	2.96	3.12	3.24
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Na	2.40	2.30	2.40	4.73	8.53	12.10	14.41	18.36	20.20	21.48	20.82	21.40	23.01	22.93	25.48
n	8	3	23	16	6	21	29	25	5	6	6	7	8	6	6
max	3.00	3.00	3.00	5.30	9.00	14.00	16.00	21.00	21.00	22.50	21.40	22.40	24.00	25.50	26.50
min	2.00	2.00	2.00	4.30	8.00	10.70	12.00	16.00	19.00	20.40	20.30	20.20	21.80	20.25	23.00
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Na	26.84	27.94	27.52	28.90	28.16	28.05	29.13	29.18	28.60	30.73	31.88	33.50	35.08	37.36	42.22
n	9	8	5	6	6	2	5	6	4	3	5	5	6	3	6
max	29.80	29.00	29.10	32.12	29.00	29.40	31.44	30.40	29.00	31.50	32.90	34.20	36.20	38.80	44.00
min	24.00	26.10	25.80	26.70	27.59	26.70	27.30	27.18	28.30	30.00	30.00	32.70	33.90	36.30	40.80
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
K	1.90	1.80	1.70	1.55	1.58	1.60	1.56	1.61	1.55	1.49	1.49	1.45	1.56	1.29	1.38
n	7	3	23	17	6	11	16	12	5	6	7	7	9	6	6
max	2.50	2.00	2.30	1.70	1.60	1.65	1.60	1.70	1.65	1.55	1.64	1.50	2.80	1.44	1.42
min	1.50	1.60	1.30	1.40	1.50	1.50	1.45	1.50	1.45	1.45	1.40	1.40	1.12	1.08	1.34
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
K	1.59	1.50	1.44	1.52	1.41	1.34	1.32	1.14	1.29	1.31	1.29	1.32	1.40	1.44	1.51
n	9	8	5	7	6	2	5	6	5	4	5	5	6	5	6
max	1.99	1.64	1.46	1.70	1.43	1.36	1.35	1.27	1.33	1.38	1.32	1.36	1.44	1.48	1.56
min	1.43	1.40	1.41	1.40	1.37	1.31	1.30	0.95	1.22	1.23	1.25	1.28	1.37	1.40	1.48

Table 6b Middle Lake anions: SO4, Cl and Gran and fixed endpoint alkalinity as ($mg \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SO_4	44.50	44.60	41.80	40.80	41.20	39.70	36.80	33.80		33.10	31.10	29.58	27.55	23.58	23.56
n	10	7	22	15	19	21	23	26		5	7	7	9	7	6
max	48.00	48.00	45.00	44.00	45.00	44.00	40.00	36.00		34.00	33.00	30.59	30.02	25.80	24.70
min	41.00	41.00	37.00	34.00	40.00	37.00	35.00	33.00		32.00	29.80	28.82	25.79	21.15	21.45
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SO_4	24.49	26.21	24.80	25.91	25.60	23.58	22.08	22.27	19.62	18.98	18.88	17.30	17.58	16.90	18.00
n	9	8	4	7	6	2	5	6	5	5	5	5	6	5	6
max	26.25	27.00	25.65	28.40	26.30	23.60	22.90	27.20	20.10	19.40	19.70	18.00	18.50	17.00	19.50
min	22.60	25.30	24.25	23.85	24.65	23.55	21.35	19.00	19.40	18.70	18.50	16.50	16.50	16.50	17.50
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cl			1.50	7.43	14.70	22.71	26.90	32.58	37.10	39.12	38.54	38.03	39.94	35.30	45.37
n			21	15	5	21	29	12	5	6	7	7	9	7	6
max			3.00	8.10	15.50	24.00	28.50	34.00	39.50	40.50	39.70	39.90	41.01	41.95	47.10
min			1.10	6.50	13.00	21.00	24.50	31.50	35.50	36.20	37.80	36.74	38.48	0.37	41.90
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cl	46.73	48.72	47.44	49.84	48.98	51.25	51.40	53.27	50.42	50.16	53.52	56.68	59.63	63.80	71.10
n	9	8	5	7	6	2	5	6	5	5	5	5	6	5	6
max	48.70	52.30	48.60	51.10	50.20	51.70	53.40	54.70	51.70	51.90	56.40	58.20	60.40	65.40	73.80
min	40.30	46.70	46.80	49.00	47.80	50.80	50.50	51.40	49.30	49.20	50.30	55.20	56.80	62.40	68.40
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Alkt (pH 4.5)	0	4.50	6.70	4.21	3.67	3.46	5.30	4.52	4.98	4.06	4.29	4.99	6.02	6.98	7.58
n	10	2	21	21	24	20	28	27	5	6	7	7	9	7	7
max		5.00	8.50	6.00	5.20	4.20	5.90	5.50	5.56	4.48	4.51	5.43	6.50	7.26	8.42
min		4.00	4.00	2.50	2.80	2.60	4.20	3.30	4.59	3.84	4.15	4.68	5.48	6.50	7.16
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alkt (pH 4.5)	8.70	7.78	7.55	7.51	7.40	7.34	8.20	8.59	9.91	11.71	9.90	10.68	11.00	12.10	12.75
n	9	8	5	6	6	2	5	6	5	5	5	5	6	5	6
max	9.17	8.43	8.07	7.80	7.74	7.59	8.61	9.36	10.60	18.40	10.20	11.60	11.50	13.00	13.50
min	8.12	7.38	7.20	7.33	6.71	7.10	7.78	7.91	9.43	9.55	9.65	9.80	10.50	11.50	11.50
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Alkti as $CaCO_3$							3.51	3.34	2.73	2.16	2.42	3.09	3.99	5.09	5.87
n							9	5	6	7	7	10	13	12	12
max							4.4	3.5	3.18	2.4	2.72	3.52	4.68	5.51	6.56
min							2.14	3.25	2.44	1.92	2.19	2.75	3.19	4.4	5.21
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alkti as $CaCO_3$	6.81	6.49	6.01	5.91	5.59	5.84	6.51	7.14	8.24	10.25	8.12	8.96	9.19	10.1	10.85
n	13	13	9	7	6	2	5	6	5	5	5	5	6	5	5
max	7.48	7.77	6.67	6.96	5.9	6.03	6.69	7.81	9.02	16.8	8.48	9.31	9.73	10.9	11.75
min	6.11	5.84	5.3	5.41	5.21	5.65	6.28	6.56	7.79	8.32	7.59	8.71	8.74	9.53	10.38

Table 6c Middle Lake sums of equivalent concentrations of cations and anions plus conductivity

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cations ($\mu Eq \cdot L^{-1}$)	1025.9	1038.0		1062.9	1250.4	1414.7	1468.9	1569.1	1646.6	1758.0	1734.1	1722.1	1797.1	1722.8	1868.8
n	8	3		15	6	10	15	12	4	4	5	6	7	6	4
max	1102.4	1069.2		1197.1	1309.1	1489.4	1531.4	1729.3	1693.6	1815.4	1752.7	1784.3	1847.4	1887.1	1930.2
min	874.1	1020.9		944.4	1183.5	1334.7	1355.0	1472.5	1551.1	1675.0	1703.2	1673.0	1730.4	1523.3	1738.9
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cations ($\mu Eq \cdot L^{-1}$)	1969.1	2038.8	1957.4	2029.2	1995.9	1931.8	1969.6	2063.0	1469.2	1712.1	2094.2	2178.0	2251.7	2357.5	2606.0
n	8	8	3	6	6	2	5	6	5	4	5	5	6	4	5
max	2124.6	2094.3	2059.3	2247.9	2020.6	2009.0	2161.4	2205.4	1912.7	2110.4	2142.3	2200.0	2300.0	2440.0	2700.0
min	1809.1	1950.9	1879.2	1821.6	1954.9	1854.7	1865.4	1914.3	884.0	643.3	1958.6	2130.0	2200.0	2310.0	2540.0

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Anions ($\mu Eq \cdot L^{-1}$)				1065.1	1263.4	1465.7	1524.6	1630.4	1727.0	1822.5	1781.5	1741.1	1768.2	1556.1	1855.8
n				12	4	20	23	11	5	4	5	6	7	6	4
max				1138.8	1311.5	1550.5	1594.1	1666.6	1811.3	1882.7	1813.6	1786.2	1810.3	1817.8	1891.3
min				1017.8	1220.2	1404.8	1430.0	1585.7	1667.3	1723.1	1753.3	1690.9	1702.6	569.7	1763.7
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Anions ($\mu Eq \cdot L^{-1}$)	1945.4	2032.2	1931.9	2051.0	2009.2	2034.5	2020.9	2090.6	1812.3	1989.5	2042.5	2176.0	2270.0	2392.0	2638.0
n	8	8	3	6	6	2	5	6	5	4	5	5	6	5	6
max	2027.8	2161.9	1939.5	2102.8	2047.0	2055.5	2055.7	2233.0	2006.5	2050.9	2125.5	2230.0	2320.0	2450.0	2700.0
min	1774.2	1981.1	1926.5	1979.1	1966.4	2013.5	1993.0	1999.3	1206.3	1933.6	1943.7	2120.0	2180.0	2340.0	2600.0

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
COND25 ($\mu S \cdot cm^{-1}$)	131.0	123.0	127.0	138.4	163.7	186.3	186.9	204.5	216.0	224.2	213.7	214.0	216.4	216.6	226.7
n	8	6	23	21	23	21	26	26	5	6	7	7	9	7	7
max	134.0	126.0	131.0	148.0	171.0	190.0	192.0	210.0	223.0	250.0	220.0	220.0	220.0	221.0	232.0
min	125.0	119.0	124.0	134.0	146.0	182.0	177.5	200.0	210.0	215.0	205.0	210.0	209.0	208.0	219.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
COND25 ($\mu S \cdot cm^{-1}$)	238.9	243.6	237.2	248.6	241.0	240.5	237.4	247.2	243.8	248.6	246.4	254.4	259.8	280.8	307.8
n	7	8	5	7	6	2	5	6	5	5	5	5	6	5	6
max	244.0	255.0	242.0	254.0	247.0	241.0	245.0	259.0	250.0	252.0	249.0	261.0	274.0	289.0	314.0
min	232.0	233.0	233.0	245.0	229.0	240.0	226.0	238.0	235.0	245.0	243.0	245.0	237.0	271.0	301.0

Table 6d Middle Lake pH and Dissolved Inorganic Carbon (DIC)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
pH	4.40	5.86	7.01	6.61	6.45	6.40	6.67	6.55	6.55	6.46	6.48	6.53	6.64	6.78	6.85
n	9	8	24	21	24	22	29	26	4	6	7	7	9	7	7
max	4.50	8.80	7.30	6.90	6.70	6.70	6.90	6.70	6.81	6.55	6.70	6.68	6.75	6.84	6.97
min	4.30	5.20	6.70	6.00	6.10	5.90	6.20	6.30	6.40	6.38	6.28	6.22	6.56	6.72	6.78
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
pH	6.87	6.78	6.73	6.70	6.82	6.78	6.90	6.90	6.89	6.95	7.06	7.09	7.06	7.22	7.29
n	9	8	5	6	6	2	5	6	5	5	5	5	6	5	6
max	7.00	6.89	6.83	6.85	6.89	6.79	6.99	6.98	6.96	7.27	7.16	7.15	7.18	7.31	7.33
min	6.56	6.70	6.63	6.47	6.74	6.78	6.81	6.82	6.84	6.71	6.91	7.02	6.95	7.09	7.24

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
DIC ($mg \cdot L^{-1}$)								0.60		0.78	0.76	0.92	1.27	1.40	1.54
n								11		5	6	6	9	7	6
max								0.80		1.00	0.80	1.16	1.50	1.51	1.65
min								0.40		0.60	0.66	0.77	1.06	1.24	1.42
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DIC ($mg \cdot L^{-1}$)	2.05	1.78	1.61	1.71	1.46	1.56	1.66	1.86	2.20	2.55	2.02	2.32	2.47	2.92	2.77
n	9	8	4	7	6	2	5	6	5	5	5	5	6	5	6
max	3.58	2.09	1.76	2.04	1.65	1.69	1.70	2.26	2.56	3.20	2.16	3.00	2.80	3.20	2.80
min	1.59	1.62	1.49	1.50	1.28	1.42	1.57	1.65	1.92	2.18	1.78	1.80	2.00	2.60	2.60

Table 6e Middle Lake nutrients: TP, NH_4-N, NO_3-N, TKN as ($\mu g \cdot L^{-1}$) and SiO_3 as ($mg \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
TP	7.3	4.4	7.1	7.0	14.6	13.2	10.7	5.9	5.8	3.6	4.4	5.5	5.6	5.6	4.8
n	10	7	24	17	23	21	28	28	5	5	7	7	9	7	7
max	14.0	9.0	20.0	16.0	33.6	29.0	19.0	7.2	6.4	4.8	5.3	7.1	7.1	7.0	6.3
min	1.0	1.0	1.0	3.0	3.5	2.5	4.0	4.6	4.8	2.6	3.7	4.7	4.3	4.6	2.6
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TP	4.8	5.3	5.8	5.5	4.6	4.2	3.8	5.2	5.1	5.4	5.6	6.8	5.0	4.4	6.0
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	5
max	6.0	7.6	7.4	7.0	5.5	4.6	5.4	6.0	6.0	6.8	9.6	14.0	10.0	10.0	8.0
min	3.2	3.0	3.0	3.4	4.2	3.8	2.5	3.8	4.0	4.5	3.8	4.0	2.0	2.0	4.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
NH_4^+-N	38.0	27.5	48.3	27.2	60.5	64.6	49.0	63.1	38.0	13.3	24.1	8.0	10.1	3.6	5.1
n	10	8	24	18	19	20	26	27	5	6	7	7	9	7	7
max	80.0	60.0	110.0	90.0	120.0	140.0	92.0	152.0	70.0	31.0	72.0	19.0	27.0	9.0	17.0
min	10.0	10.0	10.0	0.5	10.0	10.0	4.0	16.0	14.0	3.0	1.0	2.0	1.0	0.5	1.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NH_4^+-N	22.0	18.9	17.2	17.1	8.0	20.5	8.0	18.5	18.8	29.2	26.6	9.2	11.0	13.2	15.7
n	9	8	5	7	6	2	5	6	5	5	5	5	6	5	6
max	46.0	34.0	24.0	24.0	10.0	23.0	10.0	44.0	41.0	53.0	30.0	20.0	16.0	34.0	26.0
min	7.0	14.0	10.0	8.0	3.0	18.0	5.0	4.0	4.0	9.0	20.0	2.0	4.0	2.0	4.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
NO_3^--N	442.0	418.0	417.0	297.7	82.9	94.3	28.4	33.0	37.6	44.2	48.9	14.1	11.3	10.6	6.4
n	9	8	22	18	14	18	22	27	5	6	7	7	9	7	7
max	583.0	486.0	596.0	574.0	195.0	220.0	85.0	115.0	65.0	80.0	90.0	46.0	40.0	55.0	25.0
min	342.0	352.0	257.0	51.0	10.0	5.0	1.0	1.0	10.0	15.0	10.0	1.0	1.0	1.0	1.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NO_3^--N	15.1	35.4	30.4	25.4	8.7	33.0	8.6	13.5	6.8	11.6	25.0	10.0	17.7	13.4	25.7
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	59.0	86.0	83.0	89.0	18.0	52.0	18.0	43.0	15.0	16.0	48.0	15.0	26.0	21.0	41.0
min	1.0	10.0	5.0	5.0	5.0	14.0	2.0	1.0	3.0	6.0	12.0	5.0	5.0	5.0	6.0

Table 6e Middle Lake nutrients cont'd: TKN and SiO_3

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
TKN	180.0	155.0	183.0	269.7	367.6	311.0	320.4	245.7	276.0	247.5	229.3	209.3	256.7	232.9	236.7
n	10	8	24	18	19	20	25	28	5	6	7	7	9	7	6
max	260.0	300.0	240.0	470.0	486.0	562.0	500.0	435.0	330.0	260.0	265.0	225.0	430.0	260.0	260.0
min	90.0	100.0	140.0	190.0	265.0	200.0	150.0	125.0	250.0	230.0	190.0	200.0	205.0	200.0	220.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TKN	227.8	264.3	274.0	278.6	236.7	265.0	252.0	263.3	290.0	280.0	260.0	296.0	256.7	288.0	306.7
n	9	7	5	7	6	2	5	6	4	5	5	5	6	5	6
max	290.0	300.0	290.0	310.0	270.0	270.0	280.0	300.0	300.0	360.0	280.0	360.0	280.0	320.0	440.0
min	170.0	230.0	260.0	240.0	210.0	260.0	220.0	220.0	280.0	240.0	240.0	260.0	240.0	280.0	260.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SiO_3	1.3	1.4	1.6	1.9	1.7	1.5	1.0	1.3	1.2	1.2	1.3	1.2	0.8	0.7	1.0
n	9	8	24	15	6	13	8	16	5	6	7	7	9	7	6
max	1.4	1.5	1.7	2.2	2.0	1.8	1.4	1.8	1.4	1.6	1.5	1.8	1.3	1.2	1.1
min	1.2	1.3	1.3	1.6	1.4	1.2	0.5	1.0	0.8	0.3	1.1	0.9	0.6	0.3	0.8
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SiO_3	1.2	1.2	1.1	1.2	1.1	1.3	1.3	1.2	1.0	0.9	1.0	0.8	1.0	0.8	1.1
n	9	8	5	7	6	2	5	6	5	5	5	5	6	5	6
max	1.5	1.6	1.7	1.3	1.3	1.6	1.5	1.5	1.4	1.0	1.4	1.0	1.2	1.0	1.2
min	1.1	0.9	0.8	1.1	1.0	1.1	1.3	0.9	0.9	0.8	0.7	0.7	0.9	0.6	0.9

Table 6f Middle Lake transparency and its determinants: Secchi depth, DOC and total and acidified chlorophyll

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Secchi (m)	10.50	11.00	2.90	3.35	2.29	4.34	4.30	4.15	4.92	5.05	6.73	4.49	3.96	3.80	4.21
n	10	7	24	21	23	22	29	28	5	6	7	7	9	6	7
max	13.00	12.50	6.80	5.30	4.50	6.20	5.40	6.30	5.20	7.20	8.20	5.40	5.00	4.30	5.20
min	8.00	6.00	1.30	2.30	1.20	2.30	2.10	2.10	4.70	3.00	5.00	4.00	3.10	3.20	3.00
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Secchi (m)	4.76	3.36	3.10	3.74	4.07	3.70	4.18	4.15	3.80	4.26	5.52	5.45	4.39	4.80	4.50
n	8	8	5	7	6	2	5	6	5	5	8	5	6	6	6
max	6.90	3.90	3.50	5.10	4.80	4.20	4.70	5.00	4.50	5.00	6.50	6.75	5.00	5.70	6.00
min	3.50	2.90	2.50	2.80	3.70	3.20	3.40	2.90	3.20	3.50	3.50	4.50	3.30	3.00	3.50

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
DOC ($mg \cdot L^{-1}$)						1.17				2.75	2.41	2.73	3.00	3.07	2.92
n						6				6	7	7	9	7	5
max						2.00				2.90	2.80	3.00	3.20	3.30	3.10
min						1.00				2.40	2.30	2.50	2.80	2.90	2.80
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DOC ($mg \cdot L^{-1}$)	3.01	2.96	3.14	3.07	3.03	2.95	3.16	3.20	3.40	2.88	2.76	3.10	3.82	3.74	3.42
n	9	8	5	7	6	2	5	6	5	5	5	5	6	5	6
max	3.40	3.10	3.30	3.40	3.20	3.00	3.20	3.50	3.80	3.10	2.90	3.30	5.00	4.20	3.60
min	2.60	2.70	3.00	2.90	2.80	2.90	3.10	2.80	2.90	2.70	2.60	2.90	3.20	3.40	3.20

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Chlrat ($mg \cdot L^{-1}$)	0.91	0.45	0.92	2.41	2.87	2.73	3.45	5.14	2.62	1.44	0.98	2.10	2.31	3.78	2.57
n	10	6	24	21	21	21	28	27	5	5	6	7	9	7	6
max	1.90	0.50	2.10	6.60	7.30	6.10	6.50	12.00	3.90	3.00	1.30	3.50	3.10	8.40	3.10
min	0.30	0.30	0.20	0.70	0.80	0.70	0.60	1.20	1.80	0.70	0.70	1.20	1.00	2.35	2.10
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chlrat ($mg \cdot L^{-1}$)	3.19	2.11	1.86	1.71	1.12	1.55	2.02	2.20	2.75	1.84	1.84	2.36	2.17	2.92	2.57
n	9	8	5	7	6	2	5	6	5	5	5	5	6	5	6
max	5.70	2.80	2.80	3.10	1.70	1.80	3.20	3.30	6.55	3.80	2.60	4.00	3.20	6.40	4.80
min	1.60	1.40	1.30	0.10	0.70	1.30	1.50	0.90	1.00	1.00	1.00	1.40	1.00	1.40	1.40

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Chlrac ($mg \cdot L^{-1}$)			0.49	2.00	2.30	1.12	2.62	3.79	1.28	1.02	0.47	1.53	1.26	2.48	1.66
n			21	19	8	19	25	27	5	5	6	7	8	7	5
max			1.20	5.70	4.20	3.80	5.40	10.00	2.70	2.30	0.80	3.10	2.40	6.80	2.30
min			0.10	0.10	0.30	0.10	0.30	0.60	0.20	0.40	0.20	0.40	0.50	0.20	0.90
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chlrac ($mg \cdot L^{-1}$)	2.01	1.62	1.05	0.66	0.28	1.30	1.02	1.23	1.61	1.50	1.00	1.00	1.50	2.00	2.17
n	9	8	4	7	5	2	4	6	5	4	5	4	6	5	6
max	4.30	2.10	1.50	1.80	0.60	1.80	1.80	1.80	4.04	3.00	1.00	1.00	3.00	5.00	4.00
min	0.90	1.00	0.80	0.10	0.10	0.80	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 6g Middle Lake total metal concentrations: Cu, Ni, Zn, Mn, Fe and Al as ($\mu g \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cu	496.0	135.8	65.9	117.0	67.7	59.7	43.0	24.8	33.8	41.3	47.3	32.5		37.3	34.3
n	6	4	13	13	14	20	28	27	5	3	3	2		6	6
max	520.0	440.0	100.0	220.0	110.0	100.0	68.0	66.0	45.0	45.0	58.0	44.0		45.0	46.0
min	468.0	30.0	42.0	68.0	42.0	36.0	25.0	7.0	24.0	36.0	33.0	21.0		16.0	22.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cu	27.8	23.8	28.0	27.5	13.2		20.0	24.7	21.8	22.6	20.9	23.6	28.9	25.7	23.7
n	8	8	3	2	3		3	6	4	5	5	5	6	5	6
max	46.0	34.0	39.0	34.0	16.0		29.0	27.0	25.0	27.0	27.5	25.2	30.5	28.6	26.0
min	20.0	16.0	22.0	21.0	8.5		11.0	23.0	20.0	20.0	17.0	22.5	24.4	21.8	20.6
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Ni	1060.0	240.0	349.0	499.0	462.0	427.0	354.0	287.0	295.0	383.3	332.7	278.0		226.7	216.7
n	7	3	13	14	14	20	29	27	4	3	3	2		6	6
max	1100.0	260.0	460.0	590.0	610.0	490.0	420.0	390.0	320.0	480.0	358.0	300.0		260.0	240.0
min	1000.0	200.0	260.0	410.0	300.0	350.0	270.0	180.0	260.0	290.0	310.0	256.0		180.0	190.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ni	193.8	205.0	253.3	240.0	118.3		163.3	191.7	150.0	159.8	163.0	159.2	166.8	139.6	126.7
n	8	8	3	2	3		3	6	4	5	5	5	6	5	6
max	280.0	240.0	280.0	250.0	120.0		210.0	200.0	160.0	170.0	180.0	169.0	190.0	154.0	135.0
min	160.0	190.0	240.0	230.0	115.0		100.0	170.0	140.0	150.0	154.0	142.0	153.0	123.0	118.0
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Zn	91.3	38.0	28.0	40.9	41.4	29.3	23.2	17.4	18.8	34.7	33.8	19.1	18.8	13.7	18.3
n	6	4	11	12	14	21	15	26	5	3	6	6	6	6	7
max	130.0	70.0	50.0	66.0	70.0	60.0	31.0	26.0	24.0	44.0	73.0	30.0	40.0	24.0	22.0
min	60.0	20.0	17.0	30.0	20.0	20.0	16.0	6.0	5.0	26.0	16.0	9.0	6.0	4.0	15.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Zn	15.7	19.0	31.7	16.3	9.8		13.0	20.5	15.8	15.5	19.7	10.2	10.8	9.5	8.6
n	7	6	3	3	3		4	6	4	5	5	5	6	5	6
max	29.0	43.0	64.0	22.0	12.0		17.0	32.0	20.0	28.0	44.2	11.6	14.8	11.0	10.7
min	9.0	11.0	14.0	12.0	7.0		6.4	13.0	10.0	12.0	9.2	9.2	8.9	7.2	6.5

Table 6g Middle Lake cont'd Changes in total metal concentrations: Mn, Fe and Al as ($\mu g \cdot L^{-1}$)

	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mn	354.0	208.0	157.0	210.7	218.8	236.2	190.2	170.7	160.6	155.0	183.8	122.7	88.7	65.6	56.9
n	5	4	3	14	8	13	16	13	5	6	7	7	9	7	7
max	380.0	360.0	170.0	290.0	280.0	270.0	280.0	270.0	188.0	166.0	208.0	149.0	125.0	108.0	91.0
min	320.0	150.0	150.0	170.0	130.0	200.0	72.0	101.0	135.0	146.0	137.0	65.0	45.0	29.0	16.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mn	77.2	61.5	92.8	81.8	54.3	60.0	39.6	54.8	52.6	78.2	36.0	19.6	37.3	32.8	27.6
n	9	8	5	6	6	2	5	6	5	5	5	5	6	5	6
max	140.0	82.0	110.0	110.0	83.0	91.0	77.0	88.0	85.0	112.0	83.0	28.5	53.1	42.4	46.6
min	23.0	45.0	74.0	57.0	1.6	29.0	20.0	24.0	33.0	22.0	12.0	10.5	20.1	20.3	11.8
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Fe	143.0	56.0	121.0	93.3	175.0	105.8	110.6	95.4	90.0	66.7	68.0	77.7	84.4	64.3	60.9
n	4	5	11	12	9	13	16	13	5	6	7	7	9	7	7
max	170.0	80.0	260.0	140.0	280.0	180.0	170.0	160.0	120.0	100.0	110.0	130.0	115.0	95.0	96.0
min	100.0	50.0	41.0	48.0	74.0	52.0	50.0	40.0	40.0	30.0	40.0	45.0	60.0	37.0	42.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Fe	78.9	61.4	75.3	63.0	38.0	79.0	32.2	59.8	50.2	50.8	42.4	55.0	70.2	37.3	38.8
n	9	8	5	6	6	2	5	6	5	5	5	5	6	5	6
max	130.0	97.0	99.0	79.0	49.0	84.0	44.0	127.0	75.0	80.0	76.0	69.0	96.5	44.6	66.8
min	55.0	46.0	56.0	44.0	24.0	74.0	20.0	29.0	32.0	24.0	16.0	35.2	53.1	22.0	23.5
	pre	post													
Year	1973	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Al			206.0	123.3	78.0	49.3	37.4	23.3	35.2	47.0	46.8	33.4	15.6	18.0	10.9
n			12	9	8	13	15	26	4	3	5	7	9	6	7
max			270.0	230.0	140.0	120.0	85.0	89.0	57.0	53.0	85.0	85.0	28.0	40.0	23.0
min			40.0	70.0	33.0	1.0	6.0	1.0	24.0	43.0	4.0	8.0	4.0	8.0	1.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Al	8.0	24.5	33.0	22.2	12.5	36.5	15.8	16.7	9.4	24.4	18.4	15.4	19.5	13.6	16.2
n	9	6	3	5	4	2	5	6	5	5	5	5	6	5	6
max	19.0	39.0	77.0	44.0	23.0	48.0	34.0	23.0	20.0	36.0	38.0	21.2	25.5	21.6	22.5
min	1.0	6.0	8.0	7.0	6.0	25.0	5.0	1.0	2.0	14.0	8.0	9.7	11.6	7.3	8.4

Table 7 Changes in average water chemistry in Hannah Lake from 1973 to 2001

7a Hannah Lake cations: Ca, Mg, Na and K as ($mg \cdot L^{-1}$)

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Ca	12.50	11.40	12.80	20.10	19.17	18.09	16.48	15.05	14.36	14.10	13.93	13.00	12.89	11.53	12.99
n	13	23	4	15	23	9	16	12	5	6	7	6	7	7	7
max	14.00	12.00	13.00	21.00	20.00	19.00	17.20	15.60	14.80	14.60	14.20	13.50	13.40	12.60	13.50
min	12.00	11.00	12.00	19.00	18.00	17.00	15.60	14.20	13.80	13.60	13.70	12.60	12.20	9.75	12.60
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ca	13.84	13.42	13.22	13.12	12.57	11.45	11.38	11.58	8.85	10.84	10.88	11.16	11.63	11.34	11.47
n	8	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	14.50	14.50	14.10	13.88	13.30	11.70	13.16	15.60	11.10	11.40	11.80	11.30	11.90	11.40	11.80
min	13.50	12.30	11.80	12.16	11.90	11.20	10.20	6.92	4.00	10.20	10.20	10.80	11.30	11.10	10.60
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mg	4.30	3.60	4.30	3.80	4.13	4.77	4.53	3.85	4.21	4.44	4.28	4.14	4.04	3.84	4.21
n	12	22	4	16	23	11	16	12	4	6	7	6	9	7	7
max	7.00	4.00	5.00	4.00	5.00	5.10	4.75	4.10	4.55	4.60	4.34	4.48	4.33	4.18	4.30
min	2.00	3.00	4.00	3.00	4.00	4.60	4.40	3.70	3.60	4.30	4.22	4.02	3.60	3.31	4.12
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mg	4.52	4.70	4.46	4.50	4.30	3.99	3.95	4.18	2.79	3.25	3.69	3.85	3.94	3.98	4.05
n	9	8	5	7	6	2	5	6	5	5	4	5	5	5	6
max	4.76	5.14	4.73	4.86	4.40	4.07	4.24	4.73	3.49	3.90	3.79	3.96	4.00	4.06	4.22
min	4.34	4.26	4.15	4.19	4.20	3.91	3.76	3.84	1.19	2.40	3.54	3.68	3.84	3.88	3.88
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Na	3.10	3.50	7.50	8.20	14.75	22.11	24.78	29.52	33.00	33.52	32.63	33.42	34.93	33.29	38.53
n	13	24	3	9	6	21	27	23	5	6	6	6	9	6	7
max	14.00	7.00	7.60	8.70	17.00	24.00	27.00	33.00	34.00	34.50	33.60	34.90	37.00	36.36	40.40
min	2.00	2.00	7.30	7.70	12.50	20.00	20.00	26.00	32.00	32.00	31.20	32.30	32.50	27.92	34.30
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Na	42.46	43.35	43.82	45.76	44.91	48.30	44.46	44.53	26.39	35.58	44.28	49.02	54.25	56.60	63.57
n	9	8	4	6	6	2	5	6	5	4	4	5	6	5	6
max	46.10	46.40	46.90	48.89	46.70	48.80	48.38	46.00	41.00	43.80	45.90	50.00	56.00	59.20	66.60
min	39.20	39.50	39.70	43.30	43.50	47.80	41.00	42.56	2.86	11.20	42.10	47.80	52.20	54.60	60.00
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
K	2.00	2.10	1.90	2.00	1.92	2.07	1.99	2.06	2.00	1.94	1.93	1.84	2.03	1.74	1.91
n	13	23	3	9	6	11	16	11	5	6	7	6	9	7	7
max	2.90	2.90		2.10	1.95	2.20	2.15	2.15	2.05	1.95	2.10	1.94	3.75	1.87	2.11
min	1.70	1.20		1.80	1.82	2.00	1.85	1.85	1.95	1.92	1.80	1.80	1.65	1.44	1.78
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
K	2.11	2.02	1.96	1.99	1.88	1.74	1.70	1.54	1.57	1.57	1.58	1.59	1.67	1.73	1.76
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	2.69	2.19	2.05	2.12	1.92	1.76	1.72	1.70	1.68	1.82	1.65	1.66	1.74	1.79	1.83
min	1.92	1.83	1.83	1.87	1.83	1.72	1.67	1.40	1.47	1.42	1.49	1.55	1.59	1.66	1.71

Table 7b Hannah Lake anions: SO4, Cl and Gran and fixed endpoint alkalinity as ($mg \cdot L^{-1}$)

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SO_4	56.8	57.6	53.0	57.7	53.6	49.8	46.7	39.8		42.6	38.4	34.1	30.5	25.9	27.6
n	15	22	3	9	19	20	23	24		5	7	6	9	7	7
max	59.0	71.0	55.0	75.0	59.0	53.0	50.0	46.0		45.0	40.6	35.9	33.0	28.6	29.8
min	54.0	27.0	49.0	43.0	49.0	46.0	36.0	36.0		39.0	36.7	32.8	28.6	23.7	26.1
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SO_4	29.9	31.9	28.5	30.9	29.4	27.1	26.6	26.0	22.4	20.0	20.1	19.9	20.1	19.2	19.8
n	9	8	4	7	6	2	5	6	5	5	4	5	6	5	6
max	33.4	35.1	30.6	33.0	31.2	27.6	27.6	32.0	23.3	20.5	21.2	21.0	21.0	20.0	21.0
min	27.0	30.1	24.5	28.6	26.6	26.6	25.3	23.2	21.8	19.5	19.2	19.0	19.5	18.5	19.5
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cl		2.7	14.7	16.2	29.4	43.5	46.5	52.5	59.0	64.8	61.9	56.1	57.7	50.8	67.2
n		20	3	9	6	21	29	12	5	5	7	6	8	7	6
max		3.5	15.0	17.0	31.0	45.0	49.0	56.0	62.5	68.0	67.5	57.3	62.3	64.5	70.5
min		2.4	14.0	15.0	26.0	42.0	45.0	49.0	57.0	62.0	58.0	54.4	51.6	0.9	62.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cl	73.8	76.6	73.0	77.4	76.5	78.6	76.3	78.7	69.8	70.4	74.0	80.4	90.3	93.5	106.3
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	76.5	80.8	75.3	79.1	79.2	78.9	77.5	82.8	71.3	71.4	79.5	83.6	92.6	96.6	113.0
min	70.0	71.1	71.4	74.9	73.5	78.2	74.4	74.9	67.9	69.8	69.3	78.6	86.8	91.0	99.6
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Alkt (pH 4.5)	0.0	0.0		7.3	5.0	5.3	6.7	9.1	5.3	5.4	7.4	10.7	12.4	13.7	14.0
n	15	24	4	16	24	22	28	25	5	6	7	7	9	7	7
max			1.0	8.5	7.0	6.8	8.2	11.4	6.8	6.2	8.8	11.9	13.3	14.0	15.3
min			<0	5.0	3.2	4.6	5.3	6.7	3.4	5.1	6.0	9.4	11.4	13.0	13.1
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alkt (pH 4.5)	15.1	13.9	13.7	13.5	13.6	13.5	13.9	14.2	15.7	15.5	16.2	18.2	18.0	17.8	18.2
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	17.0	15.5	14.8	14.0	14.1	13.7	14.4	14.9	17.0	17.8	17.0	21.6	19.5	20.0	19.5
min	13.5	13.0	13.0	12.9	12.6	13.3	13.4	13.1	14.3	10.6	15.6	16.2	16.5	16.5	17.0
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Alkti as $CaCO_3$							4.9	7.3	3.6	3.4	5.5	8.7	10.5	11.9	12.3
n							11	5	4	6	7	7	9	7	7
max							5.9	9.8	4.6	4.1	7.0	10.0	11.5	12.4	13.5
min							4.2	5.1	2.3	3.1	4.1	7.4	9.7	11.2	11.5
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alkti as $CaCO_3$	13.4	12.3	12.0	11.8	12.0	12.1	12.3	12.7	14.3	14.2	14.4	16.2	15.7	16.1	15.7
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	5
max	15.2	13.8	13.4	12.3	12.4	12.3	12.7	13.5	15.6	16.4	15.2	17.9	16.8	17.1	16.8
min	11.8	11.4	11.2	11.2	11.1	11.9	12.0	11.8	12.8	9.0	13.4	15.0	14.4	15.2	15.2

Table 7c Hannah Lake sums of equivalent concentrations of cations and anions plus conductivity

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cations ($\mu Eq \cdot L^{-1}$)	1172.9		1315.3	1673.8	1932.3	2239.8	2248.0	2329.9	2486	2594.0	2519.5	2490.5	2562.2	2398.2	2720.0
n	11		3	9	6	9	15	11	4	5	5	5	7	6	7
max	1393.8		1324.2	1715.3	2066.1	2333.0	2352.6	2489.1	2570	2640.6	2576.4	2600.8	2668.0	2562.5	2830.8
min	965.5		1309.0	1595.5	1820.6	2137.6	2058.1	2151.1	2365	2520.5	2447.6	2437.5	2422.8	2116.8	2507.7
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cations ($\mu Eq \cdot L^{-1}$)	2960.4	2994.9	2912.3	3020.6	2983.0	3046.0	2870.4	2898.7	1504.1	2004.2	2821.8	3048.0	3308.0	3372.5	3706.0
n	8	8	3	5	6	2	5	6	5	5	4	5	6	4	5
max	3121.9	3172.8	3179.4	3231.5	3106.5	3087.0	3154.2	3160.2	2486.2	2854.0	2963.0	3110.0	3400.0	3520.0	3880.0
min	2793.9	2741.2	2731.0	2886.0	2879.0	3004.9	2678.4	2612.4	434.7	745.3	2647.3	3000.0	3240.0	3310.0	3500.0

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Anions ($\mu Eq \cdot L^{-1}$)			1491.5	1669.9	1944.9	2261.4	2293.9	2303.5	2567.4	2415.2	2617.3	2429.8	2200.3	2159.1	2391.2
n			2	5	5	19	22	11	5	5	5	5	7	6	7
max			1568.0	1804.4	2066.1	2330.8	2394.5	2432.8	2647.3	2945.0	2786.7	2471.6	2588.0	2627.7	2752.4
min			1414.9	1492.1	1820.6	2145.8	2167.9	2162.5	2506.3	907.5	2546.4	2391.2	826.2	759.5	813.8
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Anions ($\mu Eq \cdot L^{-1}$)	2951.4	3059.6	2812.1	3043.2	2982.6	2993.9	2925.9	2999.2	2459.3	2740.8	2789.8	3044.0	3322.0	3394.0	3782.0
n	8	8	3	5	6	2	5	6	5	5	4	5	6	5	6
max	3088.0	3183.3	2873.0	3098.9	3078.5	3022.1	2994.3	3097.1	2738.7	2891.2	2960.4	3120.0	3400.0	3510.0	3990.0
min	2794.9	2866.8	2721.7	2978.3	2866.6	2965.8	2880.1	2866.5	1613.0	2679.0	2626.5	2980.0	3190.0	3320.0	3600.0

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
COND25 ($\mu S \cdot cm^{-1}$)	168.0	166.0	188.0	206.0	242.2	280.5	275.2	292.3	312.6	315.8	305.7	300.9	302.2	297.9	326.9
n	14	24	4	17	22	21	22	26	5	6	7	7	9	7	7
max	175.0	175.0	190.0	215.0	250.0	287.5	285.0	301.0	320.0	325.0	320.0	306.0	307.0	304.0	338.0
min	160.0	158.0	185.0	195.0	231.0	263.0	267.5	280.0	305.0	310.0	295.0	295.0	289.0	288.0	314.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
COND25 ($\mu S \cdot cm^{-1}$)	346.7	355.8	344.2	360.9	349.7	347.5	338.2	338.2	330.8	332.6	329.8	350.2	370.2	395.0	432.3
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	362.0	370.0	353.0	366.0	361.0	350.0	345.0	360.0	345.0	338.0	335.0	359.0	395.0	411.0	455.0
min	330.0	333.0	337.0	355.0	328.0	345.0	327.0	325.0	313.0	324.0	324.0	338.0	328.0	380.0	423.0

Table 7d Hannah Lake pH and Dissolved Inorganic Carbon (DIC)

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
pH	4.31	4.29	4.64	7.02	6.69	6.66	6.98	7.10	6.56	6.64	6.90	7.00	7.12	7.18	7.16
n	14	24	4	17	24	22	28	25	4	6	7	7	9	7	7
max	4.40	4.60	4.80	7.30	7.00	7.50	7.20	7.40	6.93	6.76	7.08	7.26	7.23	7.34	7.23
min	4.20	4.10	4.50	6.70	6.40	6.20	6.70	6.80	6.20	6.45	6.64	6.72	7.02	7.02	7.12
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
pH	7.19	7.10	7.07	7.11	7.16	7.14	7.24	7.23	7.17	7.13	7.34	7.38	7.40	7.47	7.52
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	7.34	7.39	7.13	7.22	7.27	7.19	7.39	7.26	7.32	7.33	7.43	7.50	7.51	7.52	7.53
min	6.77	6.99	6.98	6.94	7.09	7.09	6.97	7.18	7.07	6.83	7.20	7.26	7.29	7.41	7.50
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
DIC ($mg \cdot L^{-1}$)								1.67		1.22	1.43	2.21	2.63	2.80	2.59
n								12		6	6	6	9	7	7
max								2.40		1.50	1.71	2.53	2.83	3.01	3.00
min								0.80		0.90	1.16	1.85	2.34	2.42	1.30
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DIC ($mg \cdot L^{-1}$)	3.14	3.28	2.94	2.98	2.88	2.93	2.94	3.15	3.48	4.30	3.78	3.80	3.83	4.36	4.10
n	9	8	4	6	6	2	5	6	5	4	4	6	6	5	6
max	3.63	3.69	3.27	3.16	3.15	3.08	3.07	3.62	3.88	4.90	4.80	4.40	4.20	4.60	4.20
min	1.97	2.90	2.72	2.75	2.55	2.78	2.82	2.82	3.08	3.90	3.28	3.20	3.60	4.00	4.00

Table 7e Hannah Lake nutrients: TP, NH4-N, NO3-N, TKN as ($\mu g \cdot L^{-1}$), and SiO3 as ($mg \cdot L^{-1}$)

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
TP	8.4	5.7	4.0	3.0	11.2	13.8	8.5	7.4	6.3	5.3	5.9	7.2	5.5	6.5	6.6
n	15	19	3	8	23	20	27	25	5	6	7	7	9	7	7
max	16.0	13.0	5.0	5.0	29.0	24.0	21.0	14.0	7.7	6.2	10.3	8.8	7.4	7.3	9.0
min	2.0	1.0	2.0	1.0	2.0	4.5	1.0	2.6	5.4	4.4	4.2	6.2	4.0	5.6	4.6
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TP	5.5	7.3	6.6	5.3	5.7	5.1	3.0	5.4	7.4	6.8	5.8	7.6	4.7	7.2	6.0
n	9	8	5	7	6	2	5	6	5	5	5	5	6	5	5
max	7.6	11.8	8.6	5.6	6.9	6.4	3.8	7.4	8.6	7.7	7.0	12.0	12.0	16.0	8.0
min	3.1	3.1	5.0	4.9	4.4	3.9	1.4	4.4	6.4	5.2	4.2	4.0	2.0	2.0	4.0
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
NH_4-N	25.0	17.3	20.0	65.6	64.4	64.0	51.2	44.4	20.4	13.2	8.2	9.6	5.6	4.6	10.1
n	10	22	3	9	20	18	26	26	5	6	7	7	9	7	7
max	50.0	90.0		90.0	145.0	135.0	204.0	104.0	30.0	50.0	41.0	26.0	21.0	10.0	25.0
min	10.0	<10		30.0	20.0	10.0	8.0	4.0	12.0	1.0	0.5	3.0	1.0	0.5	2.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NH_4-N	12.8	17.6	7.4	8.6	5.3	12.5	8.6	10.1	15.4	32.0	21.8	4.0	7.7	7.2	8.0
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	36.0	60.0	10.0	18.0	10.0	16.0	12.0	16.0	34.0	60.0	29.0	6.0	14.0	8.0	24.0
min	3.0	2.0	5.0	3.0	3.0	9.0	7.0	0.5	3.0	12.0	16.0	2.0	4.0	2.0	2.0
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
NO_3^--N	658.0	576.0	688.0	524.0	296.9	147.5	90.6	50.1	58.4	57.0	42.9	36.6	19.6	25.3	19.9
n	15	23	3	9	14	19	25	26	5	5	7	7	9	7	7
max	942.0	772.0	712.0	672.0	586.0	280.0	250.0	150.0	140.0	145.0	120.0	102.0	70.0	100.0	80.0
min	501.0	401.0	661.0	416.0	125.0	10.0	1.0	1.0	5.0	15.0	1.0	1.0	3.0	2.0	1.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NO_3^--N	45.3	20.8	16.4	19.6	2.2	12.5	6.0	10.7	5.4	10.8	23.0	7.0	6.3	6.6	8.2
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	250.0	63.0	66.0	95.0	3.0	20.0	13.0	41.0	10.0	34.0	80.0	15.0	13.0	11.0	10.0
min	2.0	1.0	1.0	1.0	1.0	5.0	1.0	1.0	2.0	2.0	4.0	5.0	5.0	5.0	5.0

Table 7e Hannah Lake cont'd nutrients: TKN snd SiO_3

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
TKN	224.0	150.0	218.0	183.0	329.2	362.2	348.8	280.7	276.0	273.3	262.9	268.6	297.8	292.9	310.0
n	13	24	3	9	21	18	24	25	5	6	7	7	9	7	7
max	500.0	350.0	310.0	190.0	405.0	480.0	540.0	395.0	300.0	300.0	300.0	300.0	370.0	320.0	360.0
min	100.0	70.0	130.0	180.0	288.0	280.0	180.0	175.0	260.0	230.0	235.0	240.0	270.0	250.0	270.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TKN	264.4	297.5	300.0	305.7	290.0	325.0	250.0	270.0	300.0	300.0	270.0	292.0	273.0	296.0	320.0
n	9	8	5	7	5	2	5	6	5	5	4	5	6	5	6
max	330.0	350.0	320.0	360.0	300.0	350.0	280.0	300.0	340.0	320.0	280.0	320.0	300.0	320.0	480.0
min	180.0	210.0	280.0	280.0	280.0	300.0	200.0	220.0	260.0	260.0	240.0	260.0	240.0	280.0	260.0
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SiO_3 ($mg \cdot L^{-1}$)	0.51	0.54	1.10	1.20	0.73	0.56	0.58	0.44	0.49	0.52	0.27	0.46	0.30	0.47	0.40
n	15	22	3	8	3	13	8	14	5	6	7	6	9	7	7
max	0.61	0.80	1.10	1.60	0.80	0.90	1.35	0.90	0.95	0.70	0.64	0.92	0.64	0.98	0.63
min	0.45	0.38	1.00	0.95	0.70	0.30	0.10	0.10	0.10	0.25	0.04	0.11	0.10	0.20	0.10
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SiO_3 ($mg \cdot L^{-1}$)	0.59	0.66	0.48	0.45	0.47	0.58	0.31	0.40	0.38	0.44	0.42	0.18	0.41	0.39	0.51
n	9	8	5	7	6	2	5	6	5	5	4	5	6	5	6
max	0.96	1.02	1.00	0.64	0.60	0.74	0.40	0.68	0.58	0.54	0.82	0.34	0.62	0.48	0.68
min	0.34	0.36	0.24	0.30	0.38	0.42	0.24	0.24	0.22	0.32	0.20	0.08	0.20	0.24	0.36

Table 7f Hannah Lake transparency and its determinants: Secchi depth, DOC and total and acidified chlorophyll

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Secchi (m)	7.40	6.20	4.80	6.00	3.28	2.62	4.54	3.89	5.10	3.52	4.89	3.37	4.04	3.53	3.43
n	17	24	4	17	23	22	29	26	5	6	7	7	9	6	6
max	8.50	8.00	6.00	7.50	5.00	4.30	5.80	4.90	6.90	4.10	6.00	4.30	6.00	4.50	4.90
min	5.00	3.00	4.00	2.50	2.00	1.30	3.20	2.60	3.80	2.90	3.50	2.50	2.40	2.90	2.60
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Secchi (m)	4.26	3.49	3.82	3.81	3.67	4.05	5.30	4.68	3.48	3.24	4.81	4.45	4.20	4.62	4.33
n	9	8	5	7	6	2	5	6	5	5	8	5	6	6	6
max	5.60	4.20	4.50	4.70	4.30	5.20	6.00	5.00	4.10	4.30	5.50	6.00	5.00	6.00	6.50
min	3.10	2.00	2.60	3.30	2.80	2.90	4.20	4.30	2.70	2.50	3.50	3.50	3.60	3.00	2.90

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
DOC ($mg \cdot L^{-1}$)						1.00				2.88	2.89	3.17	3.62	3.73	3.29
n						5				6	7	6	9	7	7
max						1.00				3.20	3.10	3.40	3.90	3.90	3.50
min						1.00				2.40	2.50	2.80	3.40	3.60	3.10
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DOC ($mg \cdot L^{-1}$)	3.22	3.41	3.50	3.67	3.65	3.20	3.32	3.37	3.24	3.16	2.92	3.17	3.58	3.86	3.52
n	9	8	5	7	6	2	5	6	5	5	4	6	6	5	6
max	3.50	3.80	3.60	4.00	3.80	3.30	3.60	3.70	3.60	3.30	3.20	3.30	3.80	4.50	4.00
min	2.80	2.80	3.40	3.20	3.30	3.10	3.10	2.80	2.40	3.10	2.70	3.10	3.20	3.60	3.30

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Chlrat ($mg \cdot L^{-1}$)	0.78	0.68	1.20	0.74	2.66	4.36	2.61	4.29	2.00	2.36	1.13	2.21	1.83	2.89	2.15
n	15	24	4	17	23	22	28	25	5	5	7	7	9	7	6
max	1.70	1.00	2.10	1.40	5.60	17.00	5.40	10.00	2.80	3.80	2.20	6.40	4.20	5.60	3.70
min	0.30	0.10	0.60	0.10	0.40	0.10	0.20	1.00	1.10	0.90	0.50	0.60	0.90	1.30	1.00
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chlrat ($mg \cdot L^{-1}$)	2.64	2.49	1.60	2.07	1.62	1.60	1.00	1.53	2.19	3.48	2.36	2.64	2.63	2.64	2.03
n	9	8	5	7	6	2	5	6	5	5	5	5	6	5	6
max	5.70	5.30	3.50	2.90	4.00	2.90	1.60	1.90	3.87	5.40	4.00	5.60	3.40	3.60	3.00
min	0.80	0.90	0.50	1.10	0.90	0.30	0.50	1.00	1.00	2.00	0.80	1.60	1.60	1.80	1.20

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Chlrac ($mg \cdot L^{-1}$)		0.38	0.68	0.63	2.22	1.90	2.04	2.78	0.72	1.86	0.69	1.73	1.11	1.79	1.68
n		21	4	15	8	19	26	25	5	5	7	7	9	7	5
max		0.70	1.20	1.40	3.60	8.50	4.00	5.90	1.90	3.00	1.30	5.60	2.40	4.40	3.20
min		0.10	0.10	0.20	1.40	0.10	0.10	0.20	0.10	0.60	0.10	0.40	0.50	0.70	0.40
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chlrac ($mg \cdot L^{-1}$)	1.51	1.94	0.76	0.90	0.64	1.10	0.42	1.02	1.49	1.75	1.60	1.00	1.83	2.00	1.67
n	9	8	5	7	5	2	5	6	5	4	5	4	6	5	6
max	4.30	4.70	1.90	2.40	1.10	1.70	0.90	1.10	2.47	3.00	3.00	1.00	2.00	3.00	3.00
min	0.30	0.60	0.40	0.40	0.20	0.50	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 7g Hannah Lake changes in total metal concentrations: Cu, Ni, Zn, Mn, Fe and Al as ($\mu g \cdot L^{-1}$)

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Cu	1090.0	1110.0	910.0	57.9	52.0	41.4	44.8	24.8	44.0	45.7	47.7	31.0		31.7	27.0
n	10	13	4	12	14	21	29	26	5	3	3	2		6	6
max	1200.0	1200.0	960.0	110.0	100.0	70.0	91.0	54.0	58.0	54.0	61.0	43.0		49.0	46.0
min	940.0	1000.0	850.0	30.0	16.0	25.0	24.0	6.0	36.0	37.0	25.0	19.0		11.0	14.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cu	18.9	18.5	21.7	22.0	11.0		18.0	23.5	21.2	19.1	20.1	22.1	22.2	20.8	23.6
n	8	8	3	3	3		3	6	4	5	4	5	6	5	6
max	35.0	34.0	33.0	31.0	14.0		27.0	29.0	31.0	27.0	28.0	29.0	33.9	25.8	32.0
min	10.0	10.0	15.0	17.0	7.0		10.0	20.0	15.0	16.2	16.1	17.5	15.0	15.5	17.4
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Ni	1620.0	1870.0	1350.0	346.0	427.0	393.0	307.0	233.0	324.0	430.0	337.3	252.5		151.7	166.7
n	10	13	4	12	14	21	29	26	5	3	3	2		6	6
max	1800.0	2200.0	1500.0	400.0	510.0	480.0	380.0	440.0	410.0	460.0	372.0	305.0		180.0	180.0
min	1480.0	1500.0	1200.0	300.0	390.0	260.0	200.0	65.0	270.0	380.0	270.0	200.0		110.0	150.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ni	178.8	180.0	190.0	160.0	78.7		131.3	161.7	123.0	110.4	140.8	154.2	153.3	134.2	138.8
n	8	8	3	3	3		3	6	3	5	4	5	6	5	6
max	270.0	220.0	210.0	200.0	85.0		170.0	180.0	160.0	140.0	152.0	187.0	194.0	151.0	147.0
min	120.0	140.0	160.0	140.0	75.0		84.0	140.0	99.0	92.2	132.0	132.0	115.0	114.0	124.0
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Zn	123.0	120.0	110.0	32.3	34.5	20.8	16.1	7.9	17.0	27.3	17.4	6.7	6.0	9.0	10.0
n	10	12	4	10	14	22	16	25	5	3	7	7	5	3	7
max	170.0	150.0	130.0	43.0	53.0	60.0	25.0	21.0	22.0	29.0	30.0	31.0	14.0	18.0	33.0
min	90.0	100.0	60.0	24.0	20.0	11.0	8.0	1.0	10.0	26.0	5.0	0.1	1.0	3.0	4.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Zn	9.0	20.8	22.9	6.7	4.5		7.7	16.9	7.7	6.9	6.0	4.0	4.1	4.0	4.3
n	4	5	3	3	3		4	6	3	5	4	5	6	5	6
max	15.0	42.0	57.0	12.0	6.0		12.3	38.0	11.0	14.0	8.2	6.5	7.0	6.1	6.6
min	5.0	5.5	3.6	4.0	1.5		2.3	7.3	4.0	3.2	3.9	2.4	2.0	2.2	2.3
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Mn	398.0	340.0	318.0	188.0	153.8	116.4	72.9	65.5	71.4	120.8	98.7	38.7	25.8	22.6	34.9
n	9	13	3	12	8	13	16	12	5	6	7	6	9	7	7
max	420.0	433.0	340.0	230.0	240.0	150.0	171.0	140.0	83.0	150.0	151.0	89.0	75.0	87.0	49.0
min	352.0	282.0	305.0	120.0	68.0	54.0	14.0	19.0	57.0	92.0	20.0	15.0	9.0	5.0	18.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mn	47.2	43.4	31.4	17.1	17.7	37.0	8.6	16.7	38.0	62.3	27.5	20.2	21.7	20.8	25.1
n	9	8	5	6	6	2	5	6	5	5	4	5	6	5	6
max	85.0	89.0	63.0	30.0	40.0	68.0	17.0	38.0	58.0	88.5	50.0	30.6	30.3	30.1	36.5
min	16.0	11.0	6.2	6.4	0.2	6.0	3.0	8.0	25.0	18.0	13.0	11.6	11.8	9.6	12.6

Table 7g Hannah Lake cont'd Changes in total metal concentrations: Fe and Al as ($\mu g \cdot L^{-1}$)

			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Fe	57.2	47.0	104.0	89.7	70.8	168.7	76.2	151.7	66.0	108.3	75.0	83.0	73.9	85.7	81.6
n	11	12	4	11	10	13	16	12	5	6	7	5	9	7	7
max	130.0	110.0	130.0	150.0	200.0	290.0	260.0	320.0	100.0	180.0	150.0	145.0	155.0	205.0	130.0
min	30.0	19.0	90.0	19.0	24.0	83.0	20.0	60.0	40.0	60.0	25.0	50.0	55.0	32.0	57.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Fe	67.2	99.4	56.6	44.5	39.5	39.5	31.0	45.5	79.6	93.0	43.0	41.1	60.6	45.2	43.8
n	9	8	4	6	6	2	5	6	5	5	4	5	6	5	6
max	130.0	230.0	79.0	69.0	62.0	56.0	81.0	74.0	96.0	117.0	58.0	52.8	90.4	56.2	56.9
min	30.0	28.0	43.0	23.0	24.0	23.0	13.0	28.0	66.0	28.0	24.0	26.0	49.2	28.9	31.6
			pre	post											
Year	1973	1974	1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Al		1100.0		92.8	66.2	63.5	43.1	26.0	19.8	53.7	35.4	27.1	21.8	22.0	12.0
n		12		10	8	11	14	24	5	3	5	7	9	6	7
max		1400.0		190.0	150.0	110.0	86.0	130.0	35.0	59.0	72.0	63.0	44.0	47.0	30.0
min		680.0		45.0	12.0	43.0	14.0	1.0	5.0	46.0	6.0	10.0	7.0	10.0	3.0
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Al	9.6	27.9	22.0	16.4	15.0	30.0	14.4	12.2	7.8	21.0	14.5	9.7	11.6	12.7	14.3
n	9	8	3	5	3	2	5	6	5	5	4	5	6	5	6
max	17.0	62.0	38.0	28.0	27.0	41.0	29.0	23.0	18.0	28.0	32.0	13.1	17.1	21.5	22.4
min	1.0	7.0	7.0	7.0	6.0	19.0	10.0	1.0	2.0	12.0	8.0	7.5	7.8	6.3	8.4

Figure 1. Location of the four study lakes:
Clearwater, Lohi, Hannah and Middle

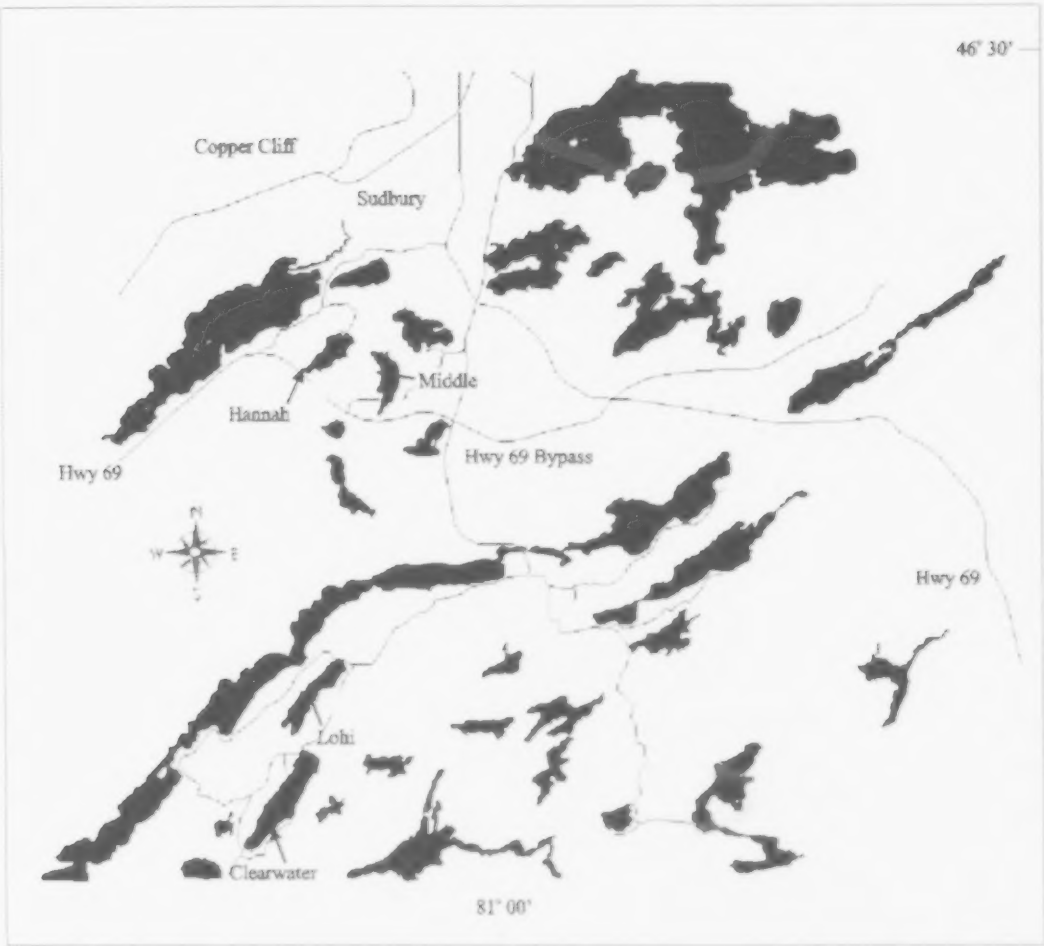


Figure 2: Bathymetric chart (depth in meters) of Clearwater Lake, showing main sampling location

Latitude	46° 22'	Area (ha)	76.5
Longitude	81° 03'	Perimeter (km)	4.97
Wshed	2CF05	Max. Depth (m)	21.5
District	Sudbury	Mean Depth (m)	8.39
Township	Tilton - Broder	Elevation (msl)	285

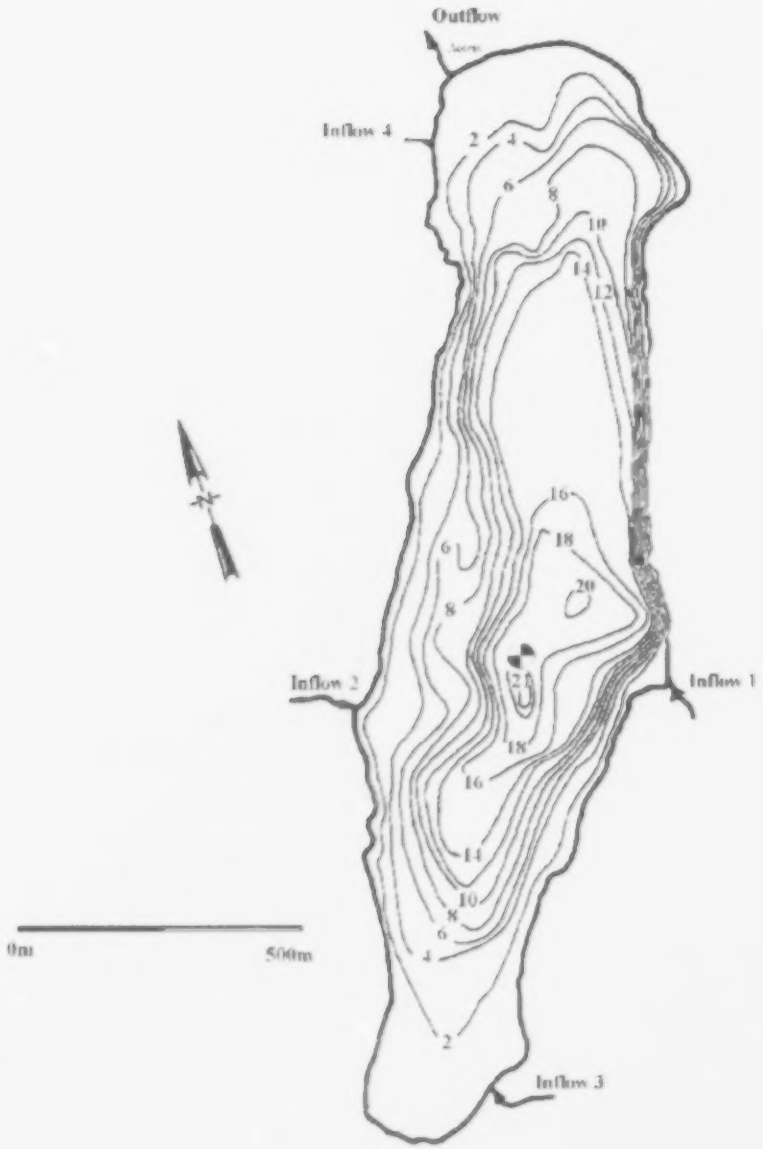


Figure 3 : Bathymetric chart (depth in meters) of Lohi Lake, showing main sampling location

Latitude	46° 23'	Area (ha)	40.5
Longitude	81° 02'	Perimeter (km)	4.47
Wshed	2CF05	Max. Depth (m)	19.5
District	Sudbury	Mean Depth (m)	6.2
Township	Broder	Elevation (msl)	282

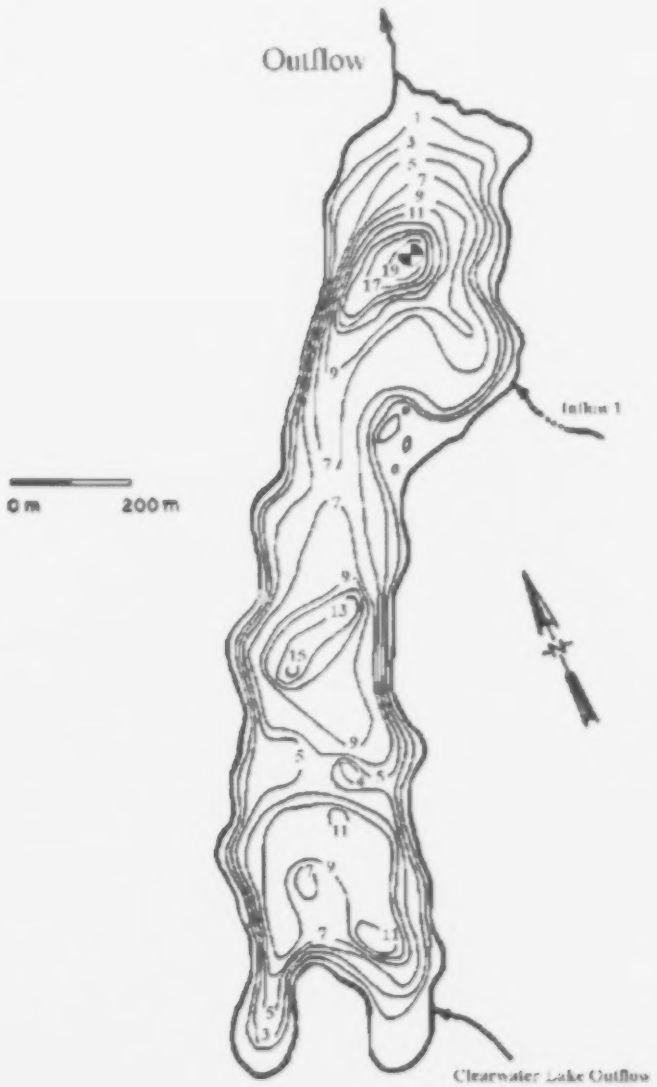


Figure 4: Bathymetric chart (depth in meters) of Middle Lake, showing main sampling location

Latitude	46° 26'	Area (ha)	28.2
Longitude	81° 02'	Perimeter (km)	3.2
Wshed	2CF08	Max. Depth (m)	15.0
District	Sudbury	Mean Depth (m)	6.2
Township	Broder	Elevation (msl)	284

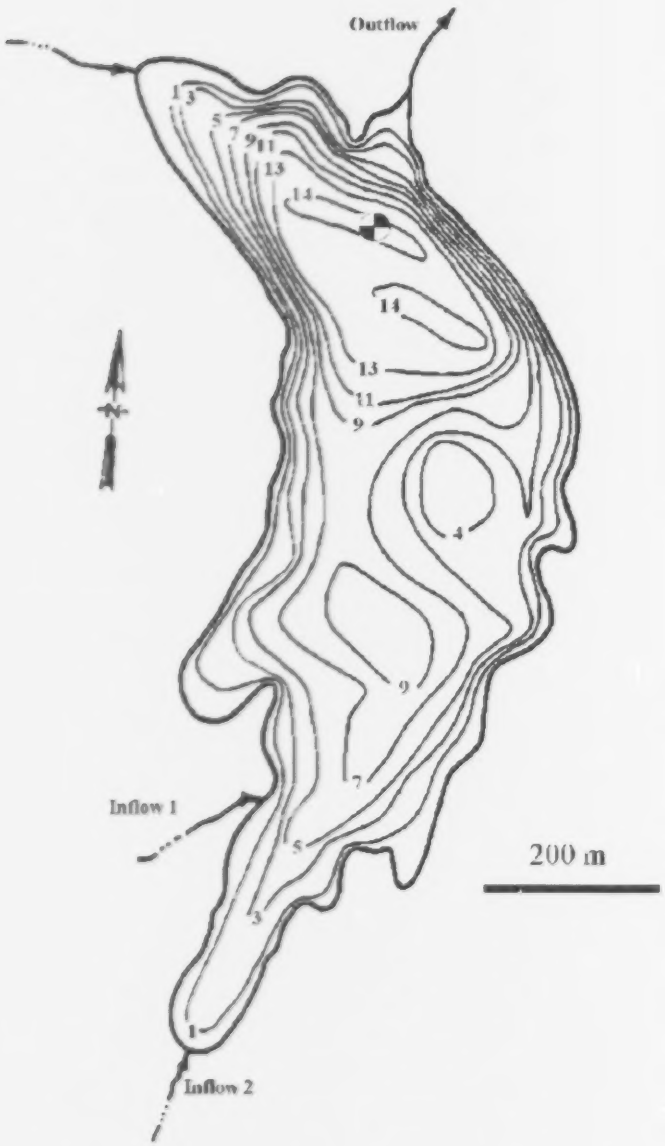


Figure 5 : Bathymetric chart (depth in meters) of Hannah Lake, showing main sampling location

Latitude	46° 27'	Area (ha)	27.3
Longitude	81° 02'	Perimeter (km)	2.7
Wshed	2CF08	Max. Depth (m)	8.5
District	Sudbury	Mean. Depth (m)	3.97
Township	Broder	Elevation (msl)	285

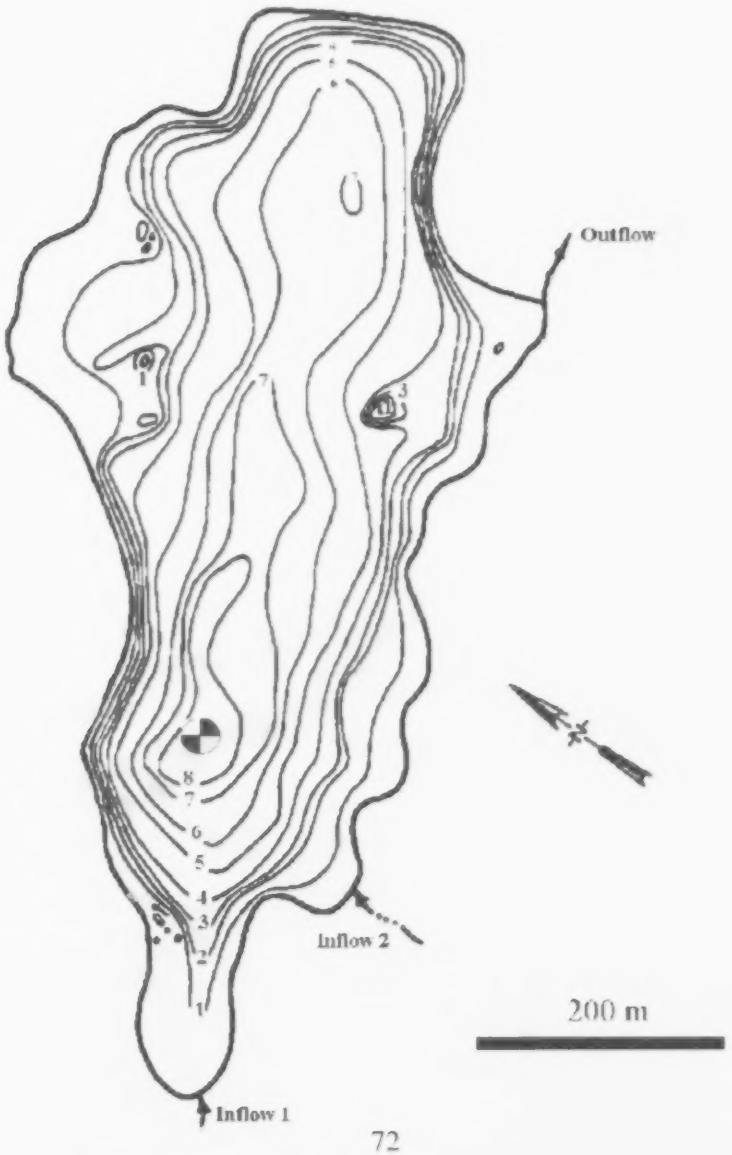


Figure 6. Long-term changes in the limnology of Clearwater Lake

6a. Base cations and pH (Ca, Mg, K, Na, pH & Monovalent to Divalent ratio)

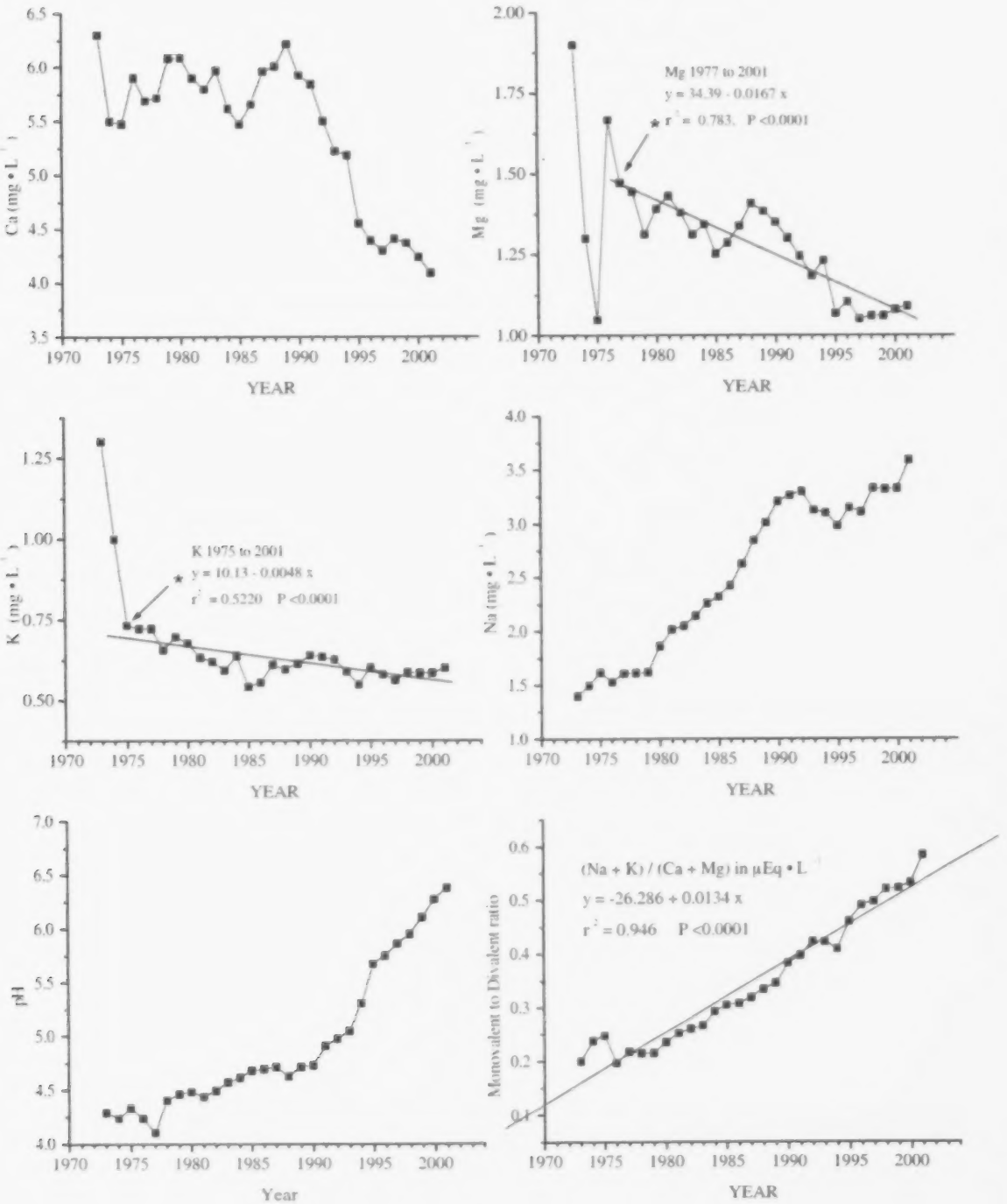


Figure 6b: Clearwater Lake Anions & related variables: (dissolved inorganic carbon (DIC), alkalinity, conductivity, and a compariso of sums of anions and cations)

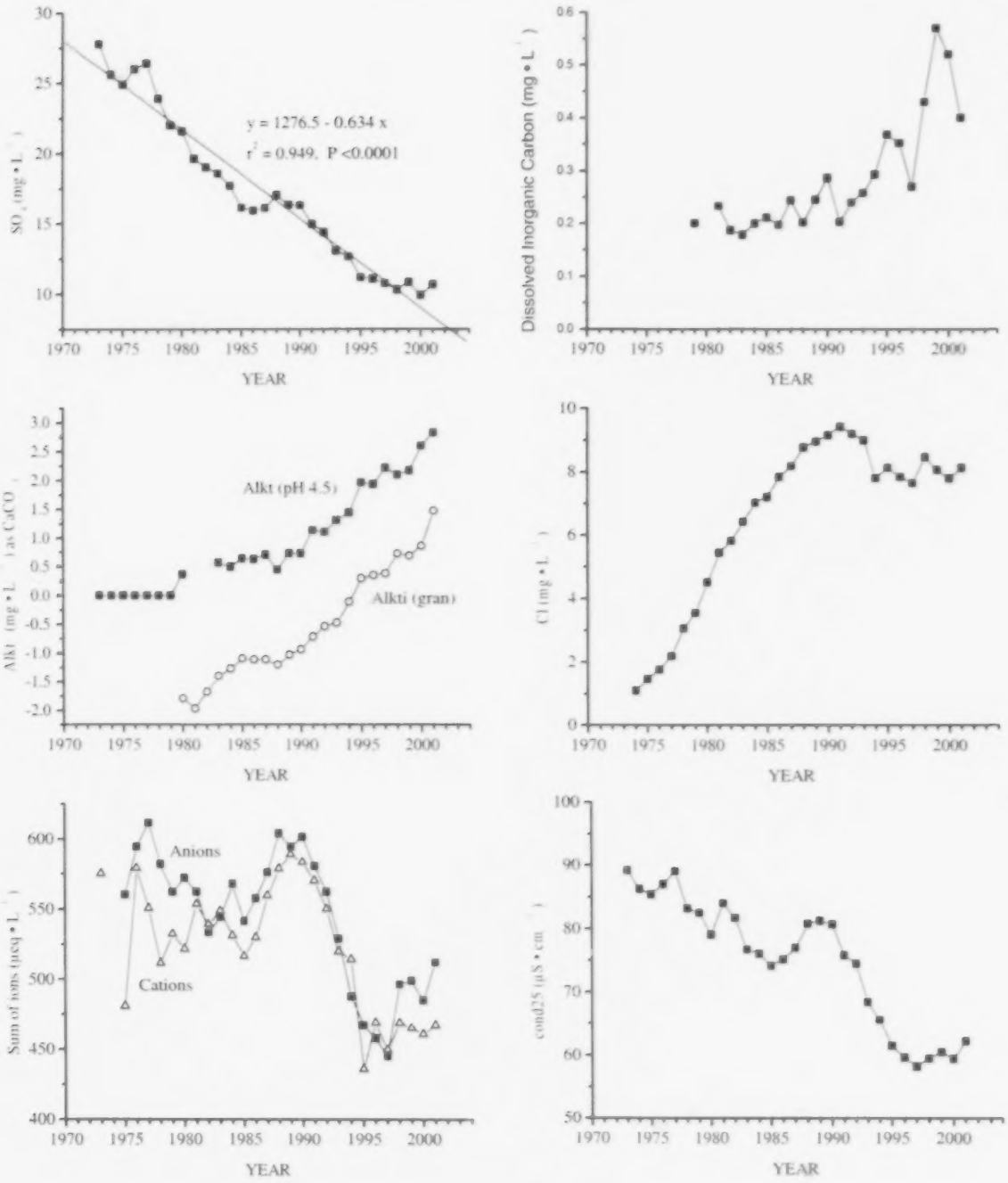


Figure 6c: Clearwater Lake Metals: (Al, Zn, Cu, Ni, Fe & Mn)

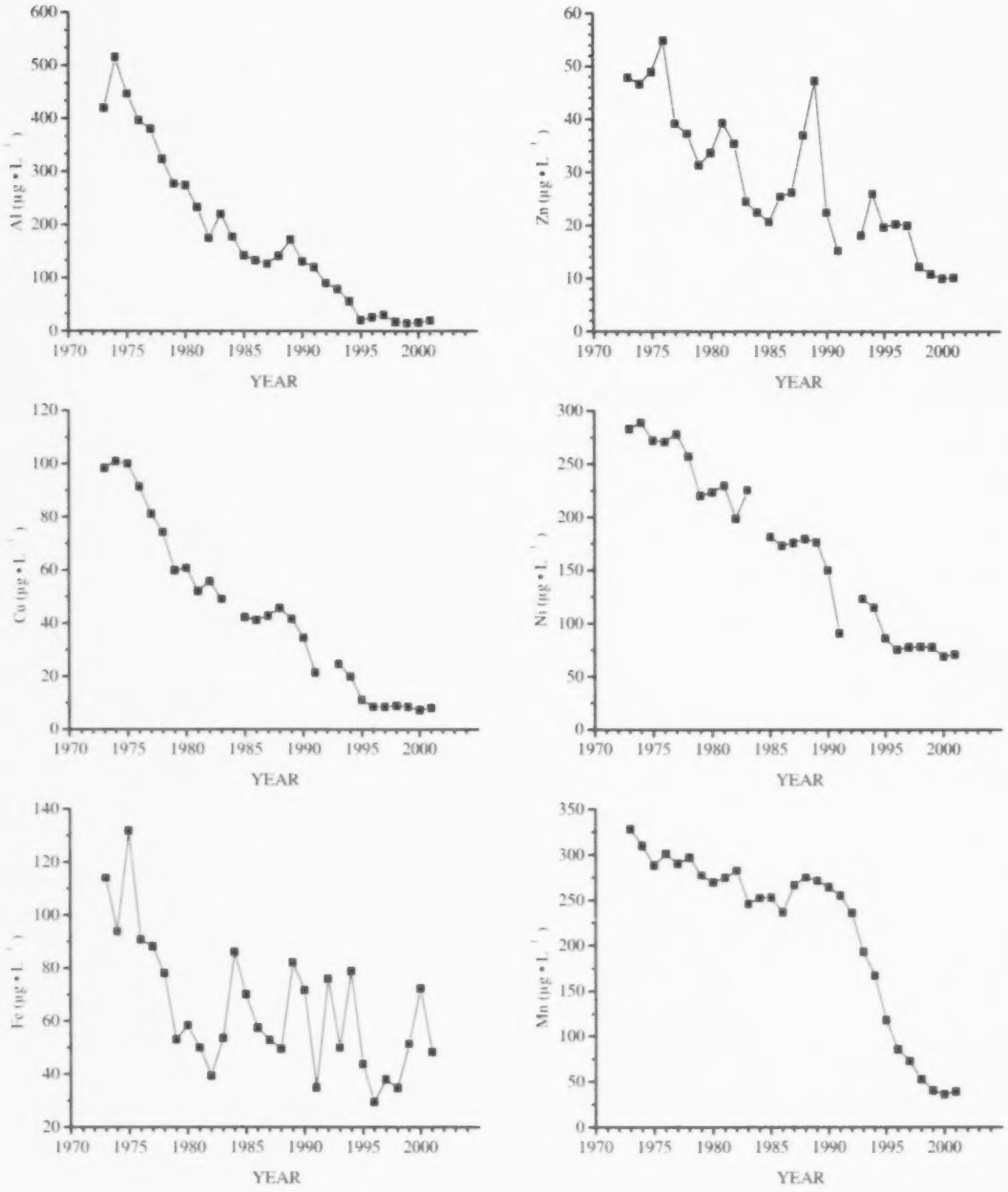
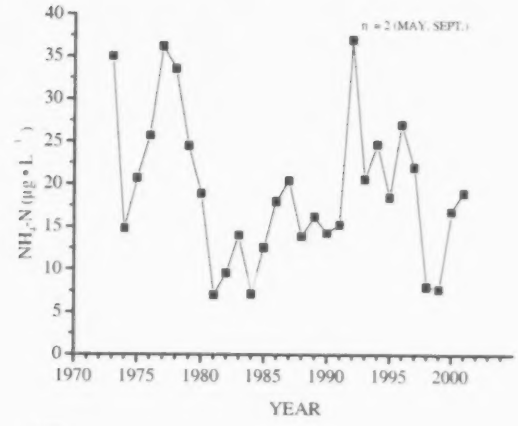
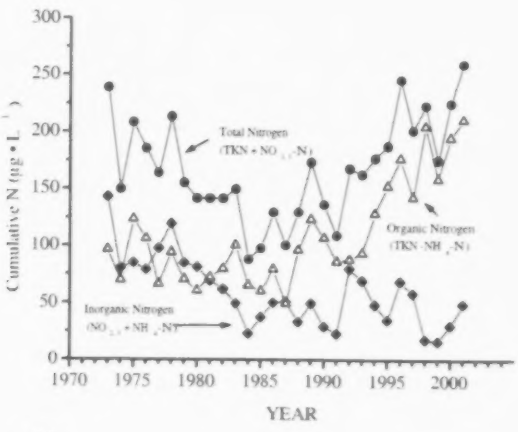
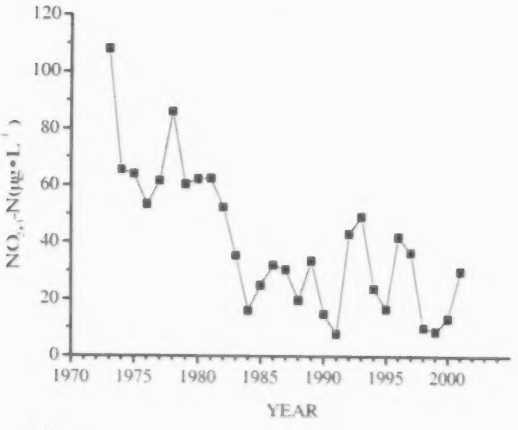
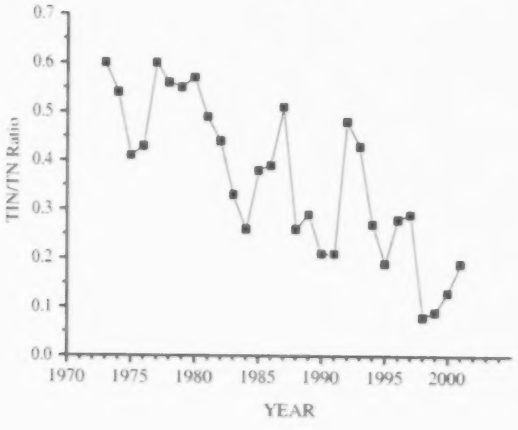


Figure 6d: Clearwater Lake - Nitrogen species and TIN / TN ratio









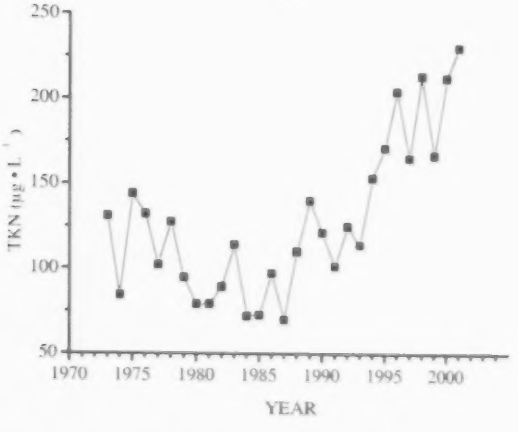


Figure 6e: Clearwater Lake - trophic indicators:
(chlorophyll, Secchi depth, dissolved organic carbon (DOC), silicate,
Total phosphorus, and TN/TP ratio)
(* year TP analysis moved away from sewage plant in Sudbury)

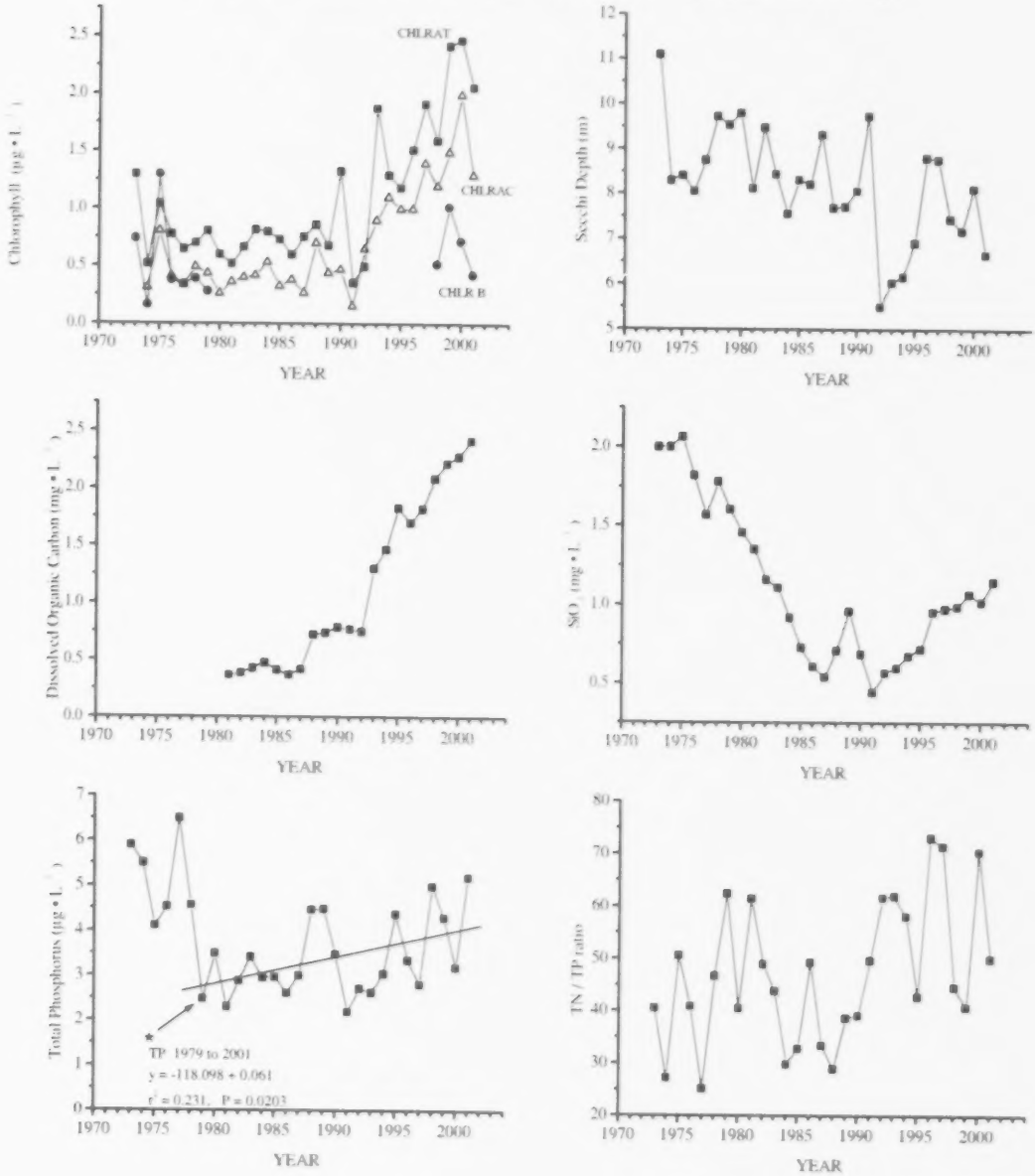


Figure 6f. Clearwater Lake changes in thermocline depth and increase of meta + hypolimnetic % total volume, and concurrent changes in mid summer surface and deep water temperatures

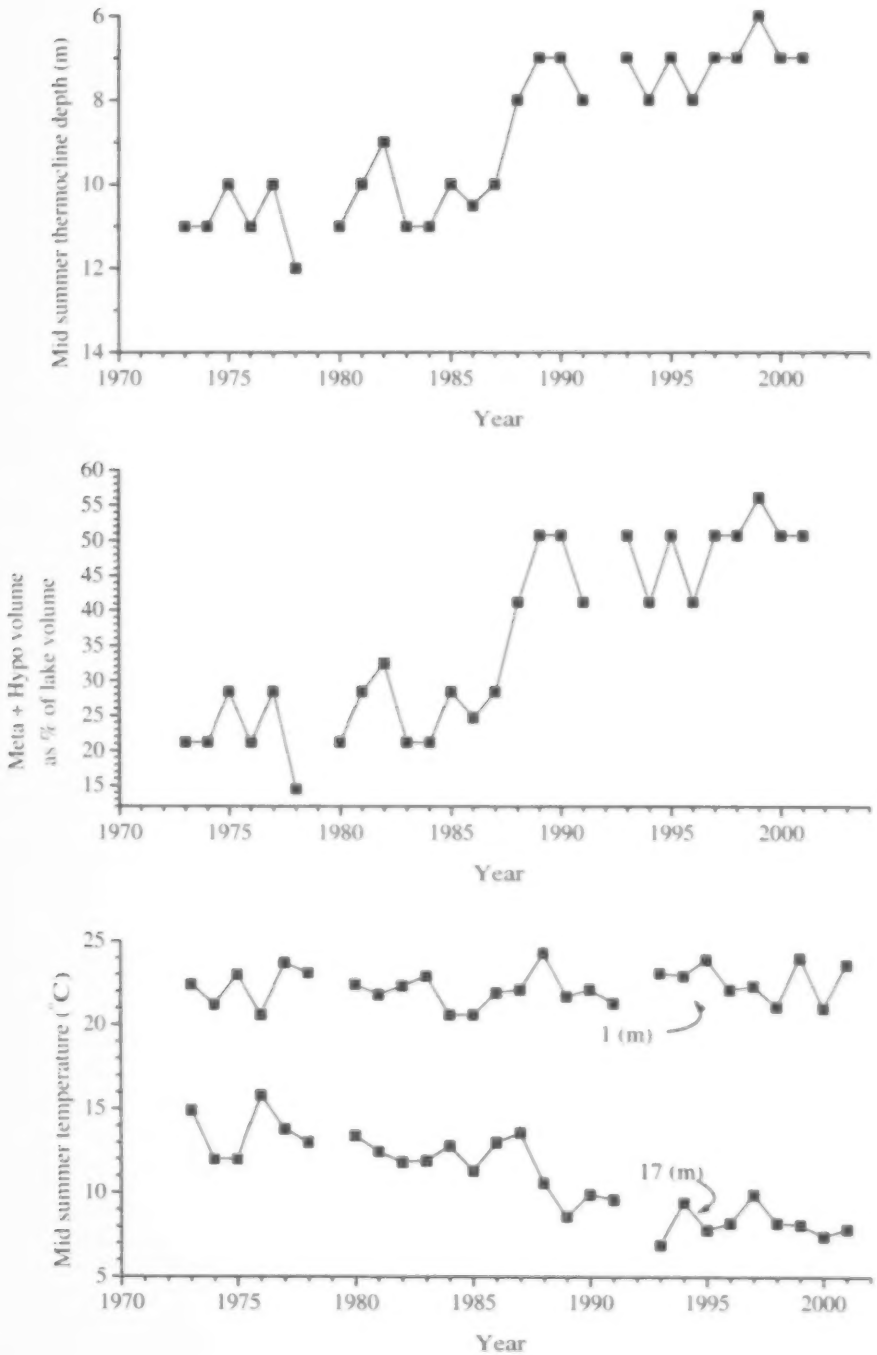


Figure 6g. Clearwater Lake changes in maximum heat content (cal • m $^{-2}$),
maximum summer heat income ($^{\circ}$C>4°C),
and volume-weighted average temperature ($^{\circ}$C)

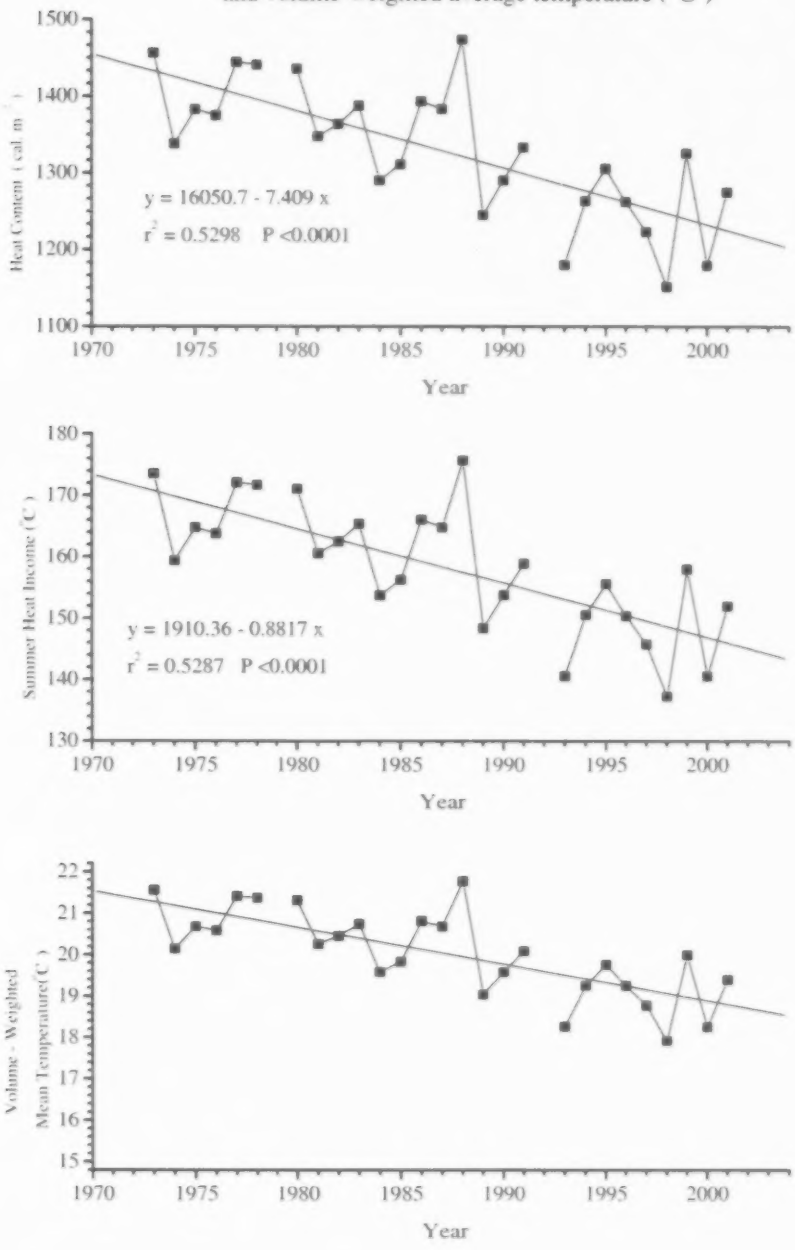
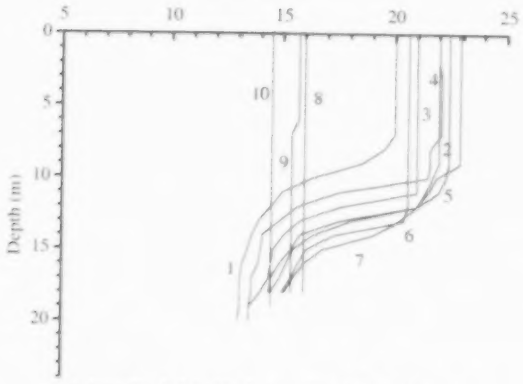


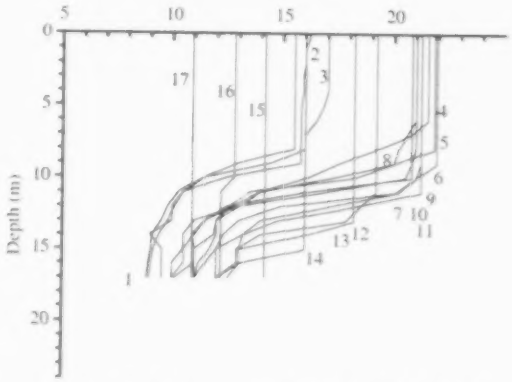
Figure 6h. Clearwater Lake - Temperature (°C) Profiles

1973



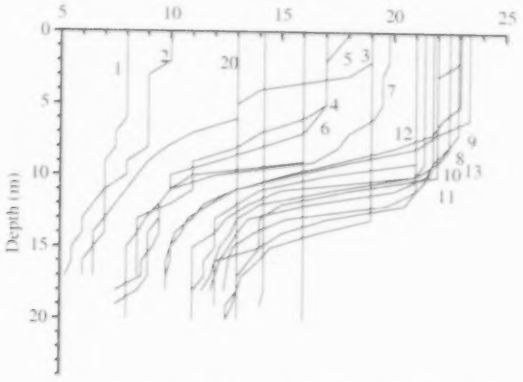
1. June 28 2. July 18 3. Aug. 02 4. Aug. 09
5. Aug. 14 6. Aug. 21 7. Aug. 28 8. Sept. 06
9. Sept. 19 10. Sept. 25 11. Oct. 03

1974



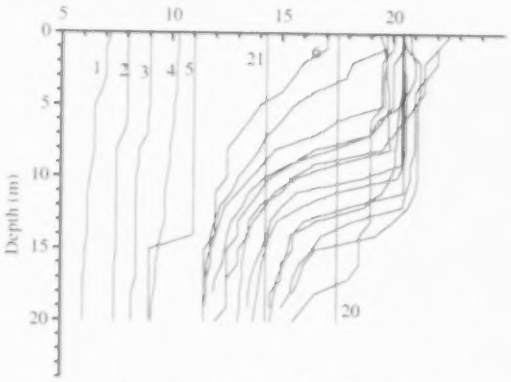
1. June 12 2. June 18 3. June 25 4. July 10 5. July 17
6. July 23 7. July 30 8. Aug. 06 9. Aug. 15
10. Aug. 20 11. Aug. 27 12. Sept. 04 13. Sept. 10
14. Sept. 18 15. Sept. 25
16. Oct. 02 17. Oct. 08

1975



1. May 13 2. May 19 3. May 26 4. June 02 5. June 10
6. June 17 7. June 23 8. July 03 9. July 07 10. July 15
11. July 22 12. July 28 13. Aug. 05 14. Aug. 12 15. Aug. 19
16. Aug. 25 17. Sept. 03 18. Sept. 15 19. Oct. 02 20. Oct. 14

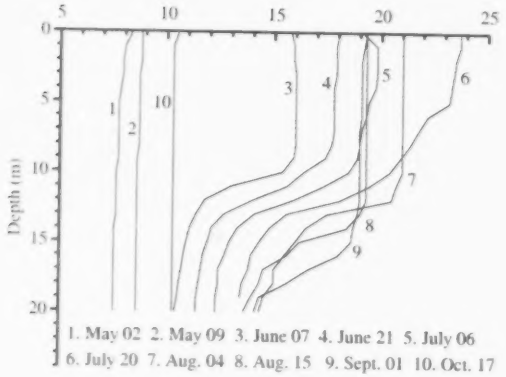
1976



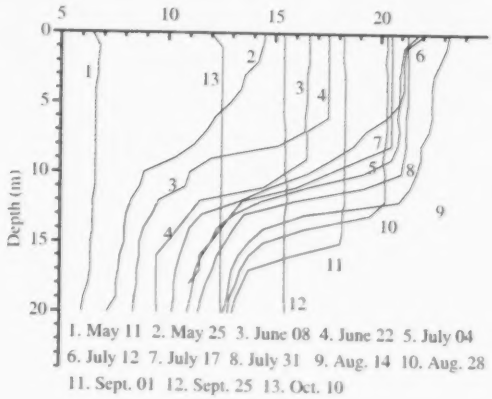
1. Apr. 29 2. May 05 3. May 11 4. May 18 5. May 25
6. May 31 7. June 07 8. June 16 9. June 21 10. June 23
11. July 06 12. July 13 13. July 21 14. July 26
15. Aug. 04 16. Aug. 10 17. Aug. 17 18. Aug. 24
19. Sept. 07 20. Sept. 20 21. Oct. 06

Figure 6h cont'd : Clearwater Lake Temperature (^{0}C) Profiles

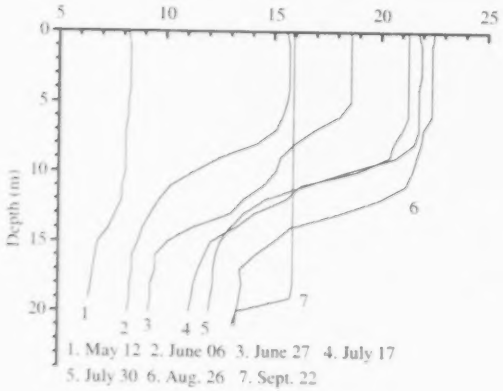
1977



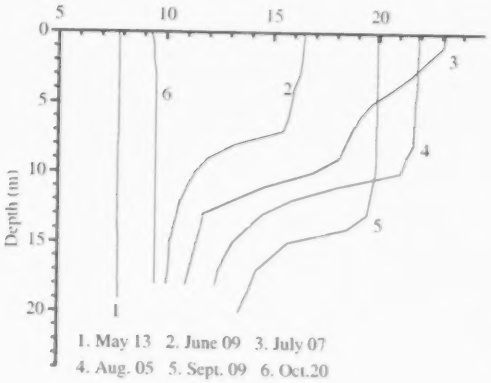
1978



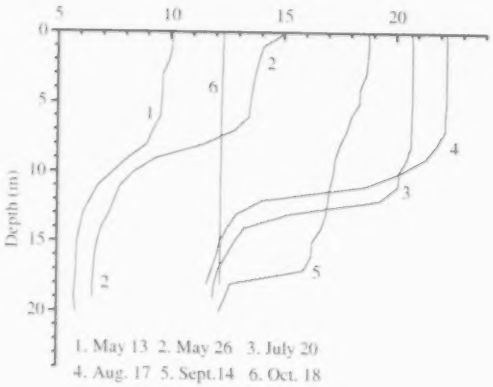
1980



1981



1982



1983

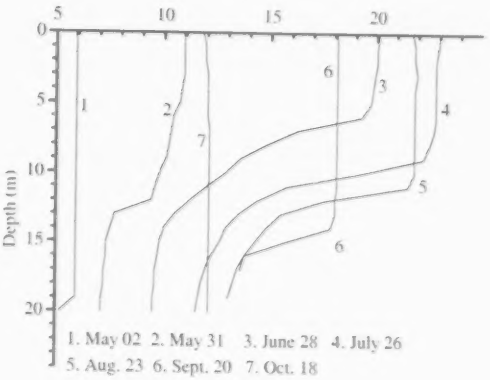


Figure 6h cont'd : Clearwater Lake - Temperature (°C) Profiles

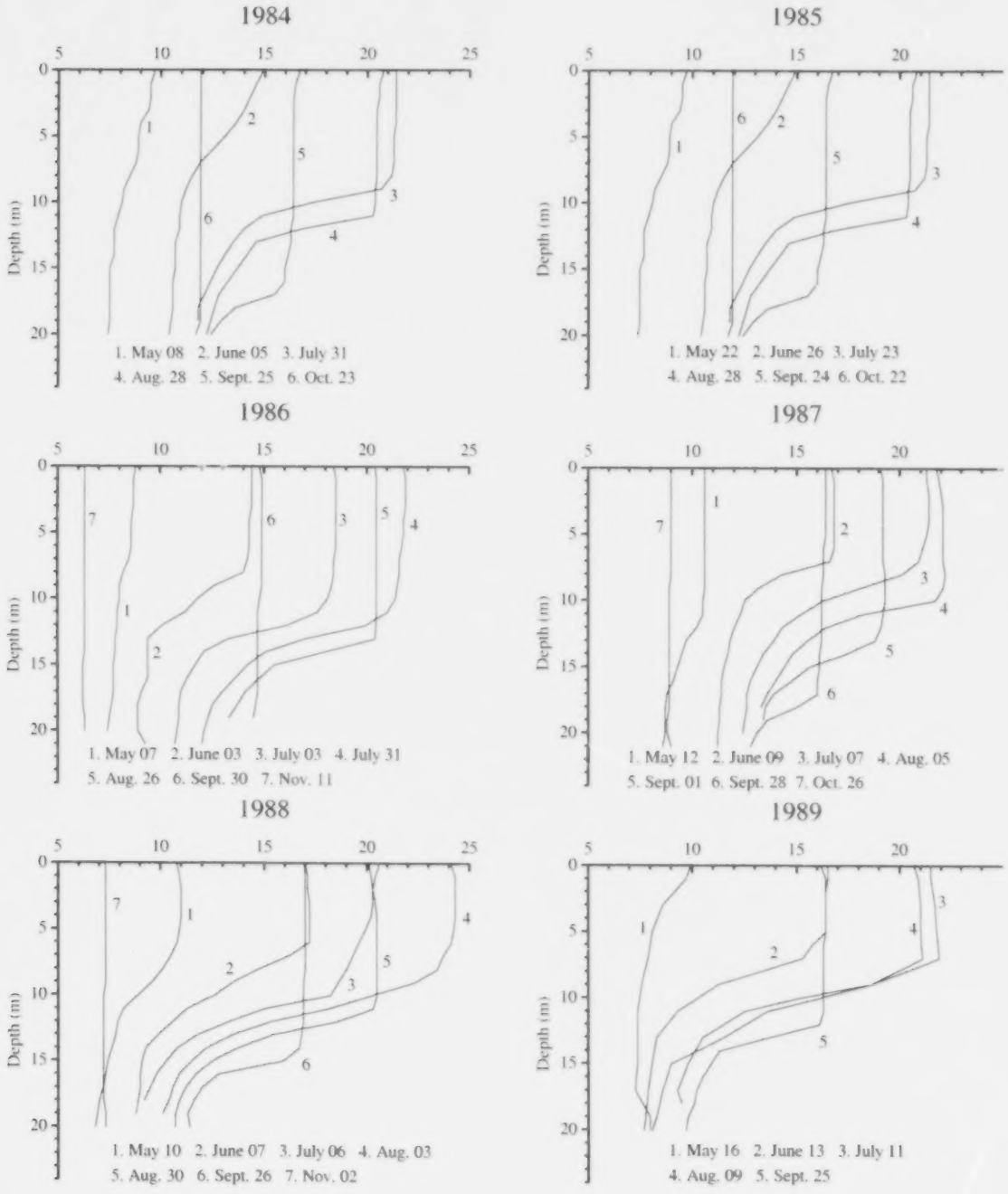

1984
1. May 08 2. June 05 3. July 31
4. Aug. 28 5. Sept. 25 6. Oct. 23
1985
1. May 22 2. June 26 3. July 23
4. Aug. 28 5. Sept. 24 6. Oct. 22
1986
1. May 07 2. June 03 3. July 03 4. July 31
5. Aug. 26 6. Sept. 30 7. Nov. 11
1987
1. May 12 2. June 09 3. July 07 4. Aug. 05
5. Sept. 01 6. Sept. 28 7. Oct. 26
1988
1. May 10 2. June 07 3. July 06 4. Aug. 03
5. Aug. 30 6. Sept. 26 7. Nov. 02
1989
1. May 16 2. June 13 3. July 11
4. Aug. 09 5. Sept. 25
Depth (m)

Figure 6h cont'd : Clearwater Lake - Temperature (°C) Profiles

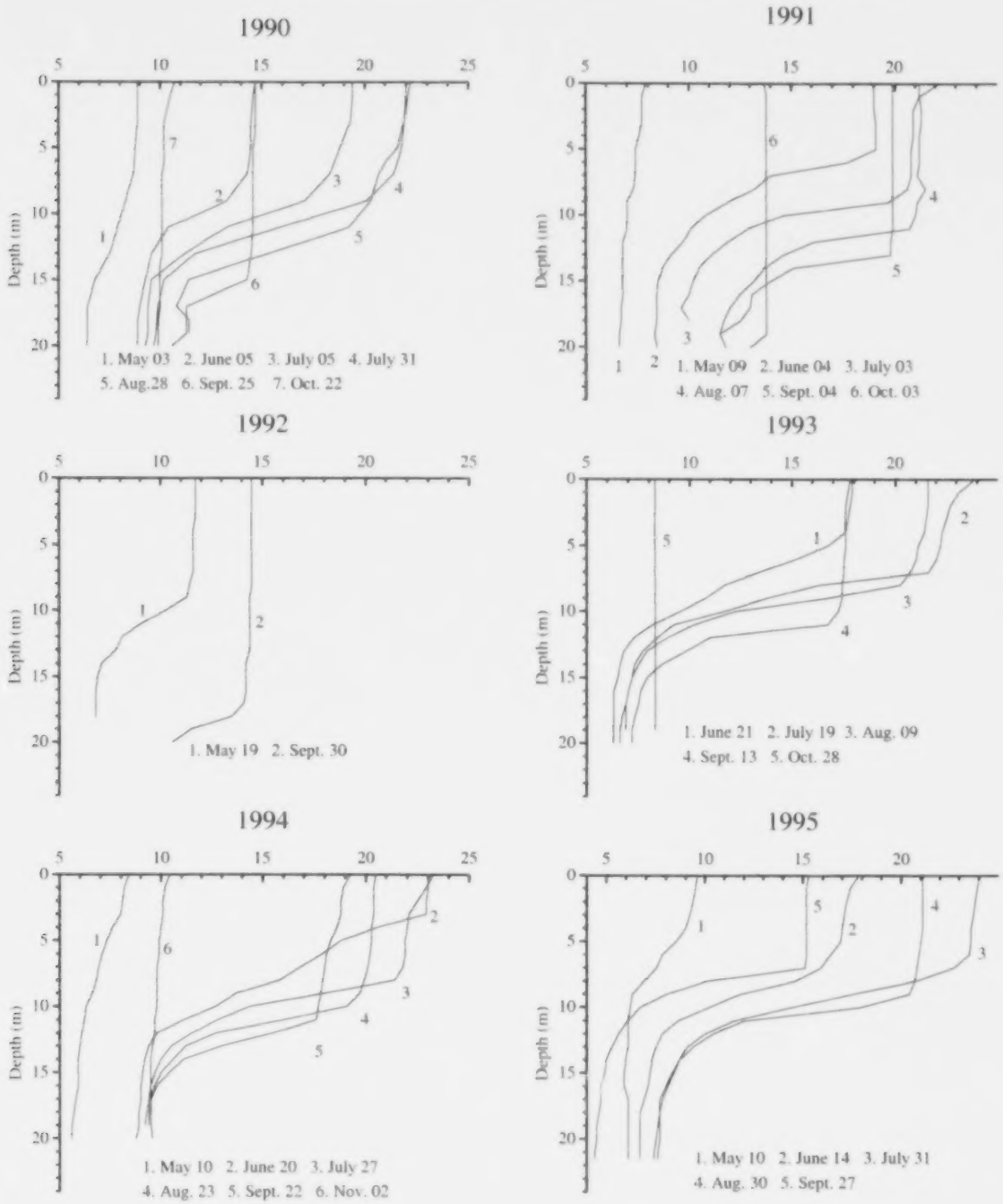


Figure 6h cont'd : Clearwater Lake - Temperature (°C) Profiles

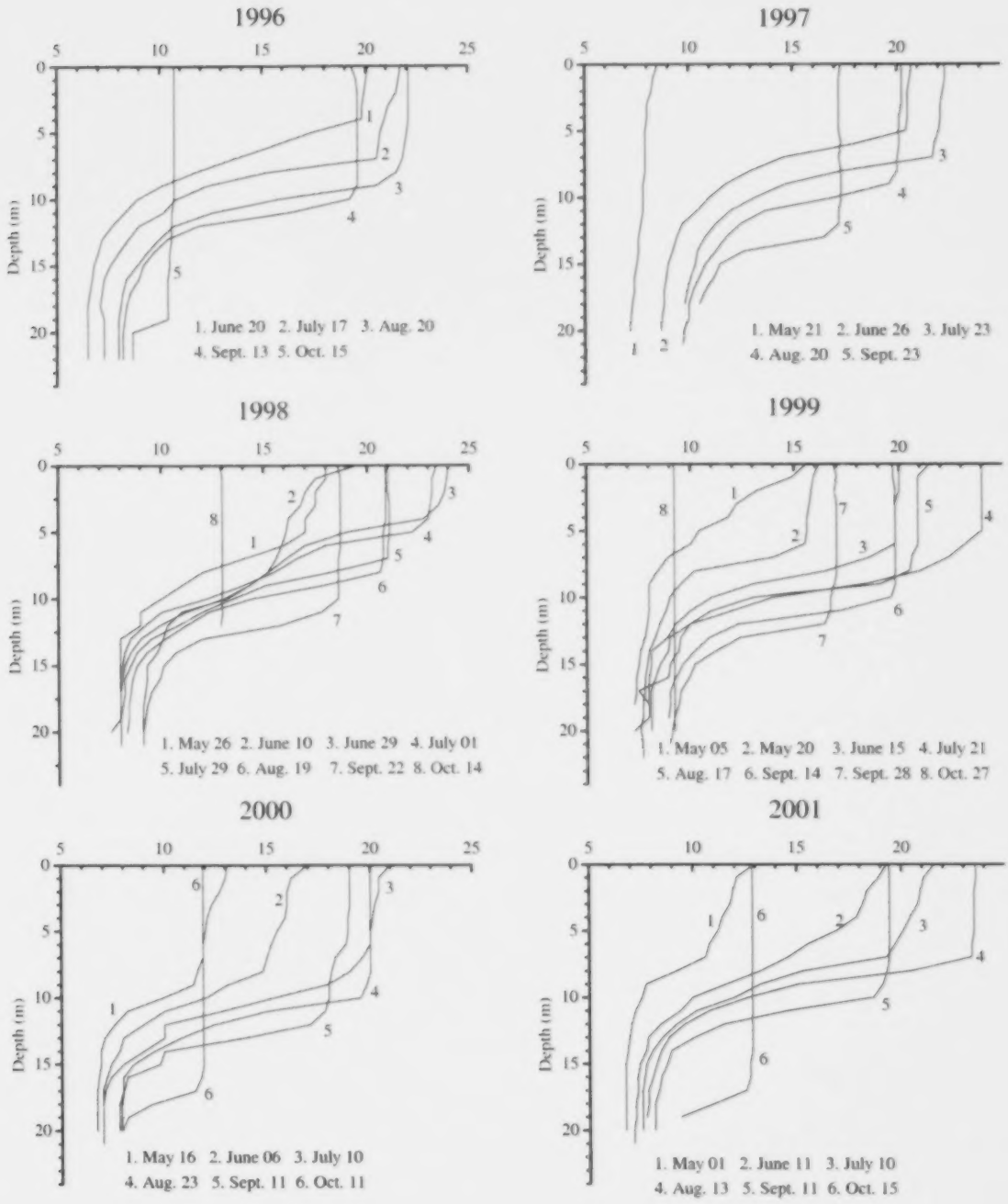

1996
1. June 20 2. July 17 3. Aug. 20
4. Sept. 13 5. Oct. 15
1997
1. May 21 2. June 26 3. July 23
4. Aug. 20 5. Sept. 23
1998
1. May 26 2. June 10 3. June 29 4. July 01
5. July 29 6. Aug. 19 7. Sept. 22 8. Oct. 14
1999
1. May 05 2. May 20 3. June 15 4. July 21
5. Aug. 17 6. Sept. 14 7. Sept. 28 8. Oct. 27
2000
1. May 16 2. June 06 3. July 10
4. Aug. 23 5. Sept. 11 6. Oct. 11
2001
1. May 01 2. June 11 3. July 10
4. Aug. 13 5. Sept. 11 6. Oct. 15
Depth (m)

Figure 6i : Clearwater Lake epilimnetic depth on the dates of maximum heat content

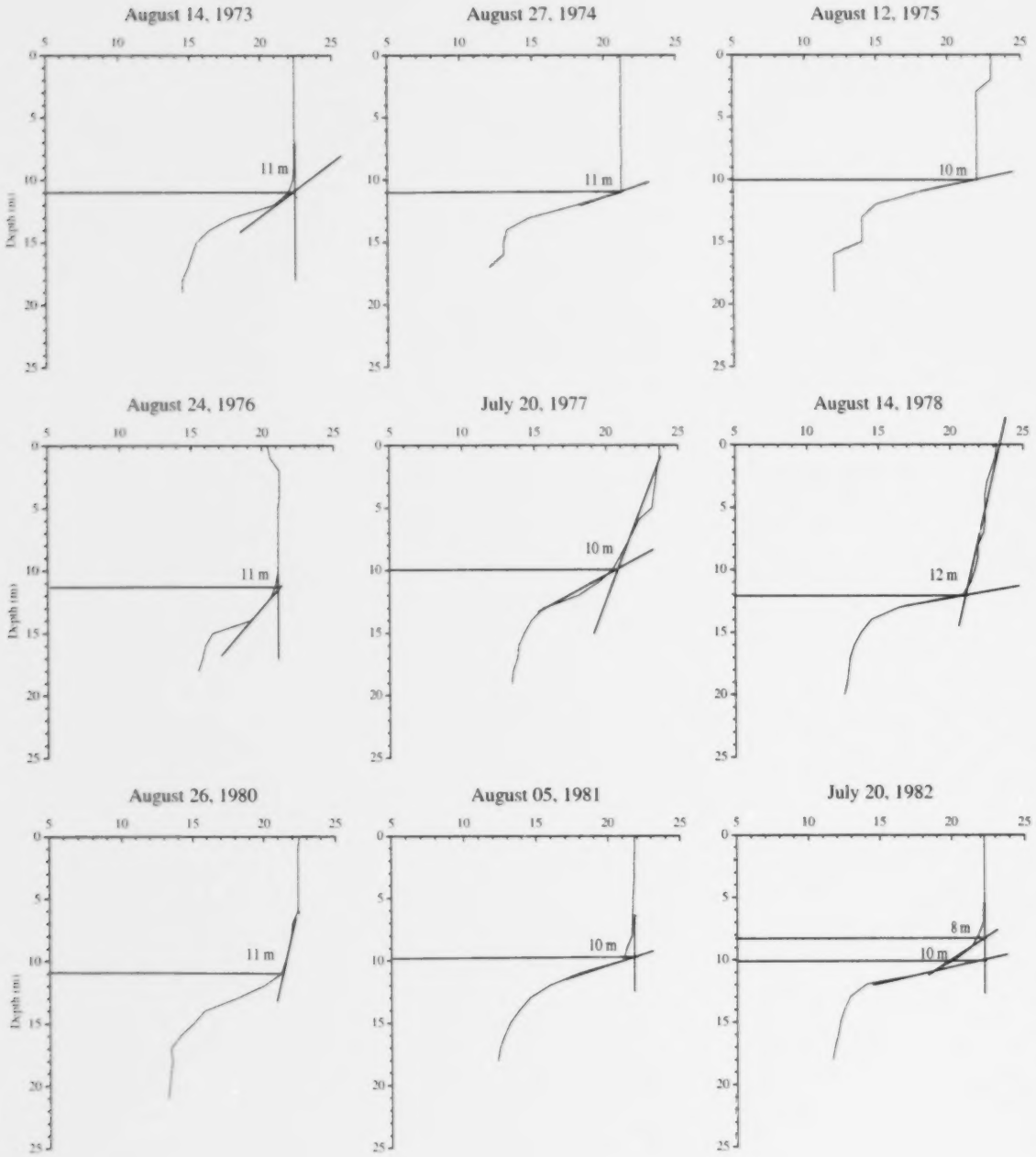


Figure 6i cont'd : Clearwater Lake epilimnetic depth on the dates of maximum heat content

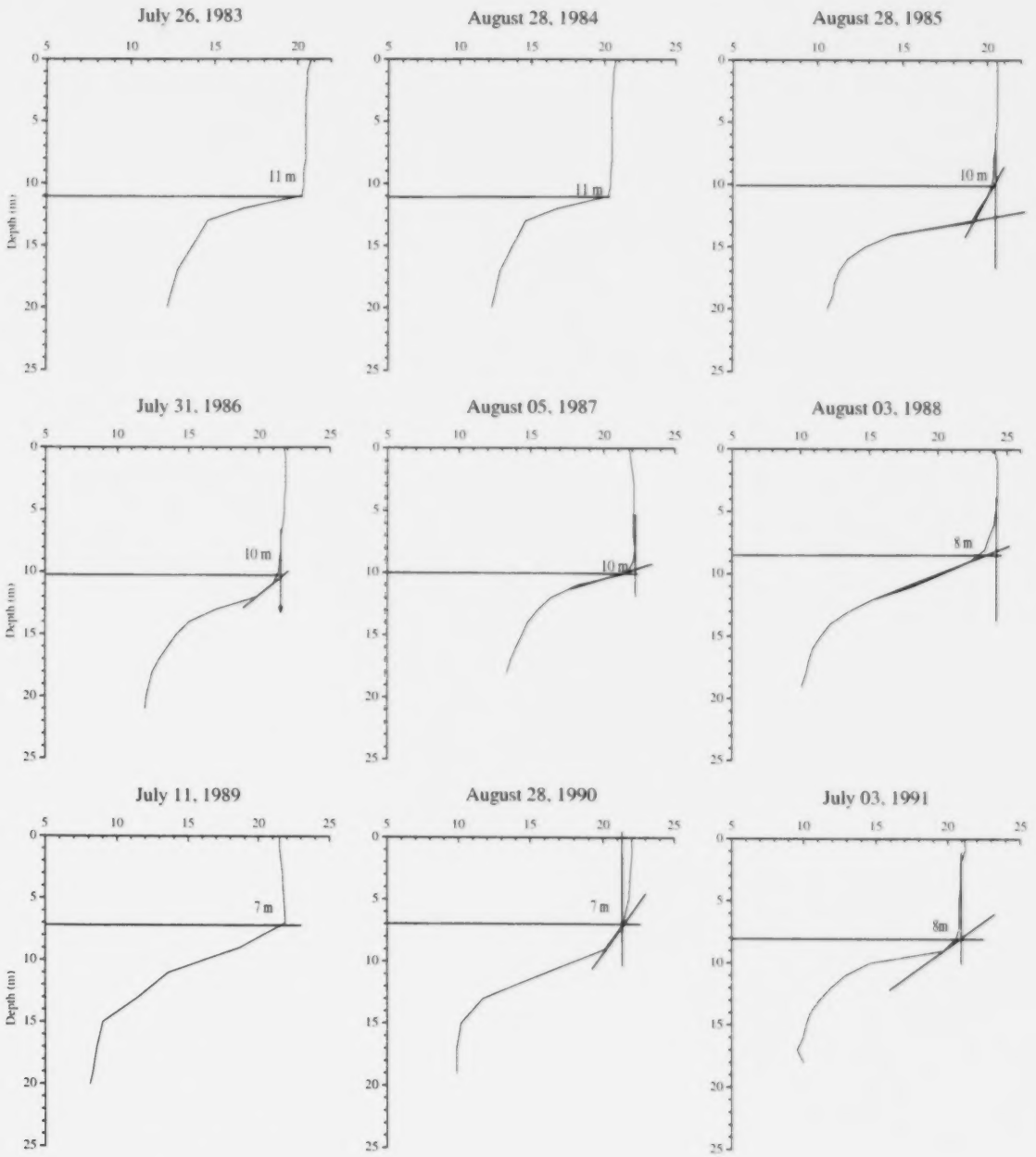


Figure 6i cont'd : Clearwater Lake epilimnetic depth on the dates of maximum heat content

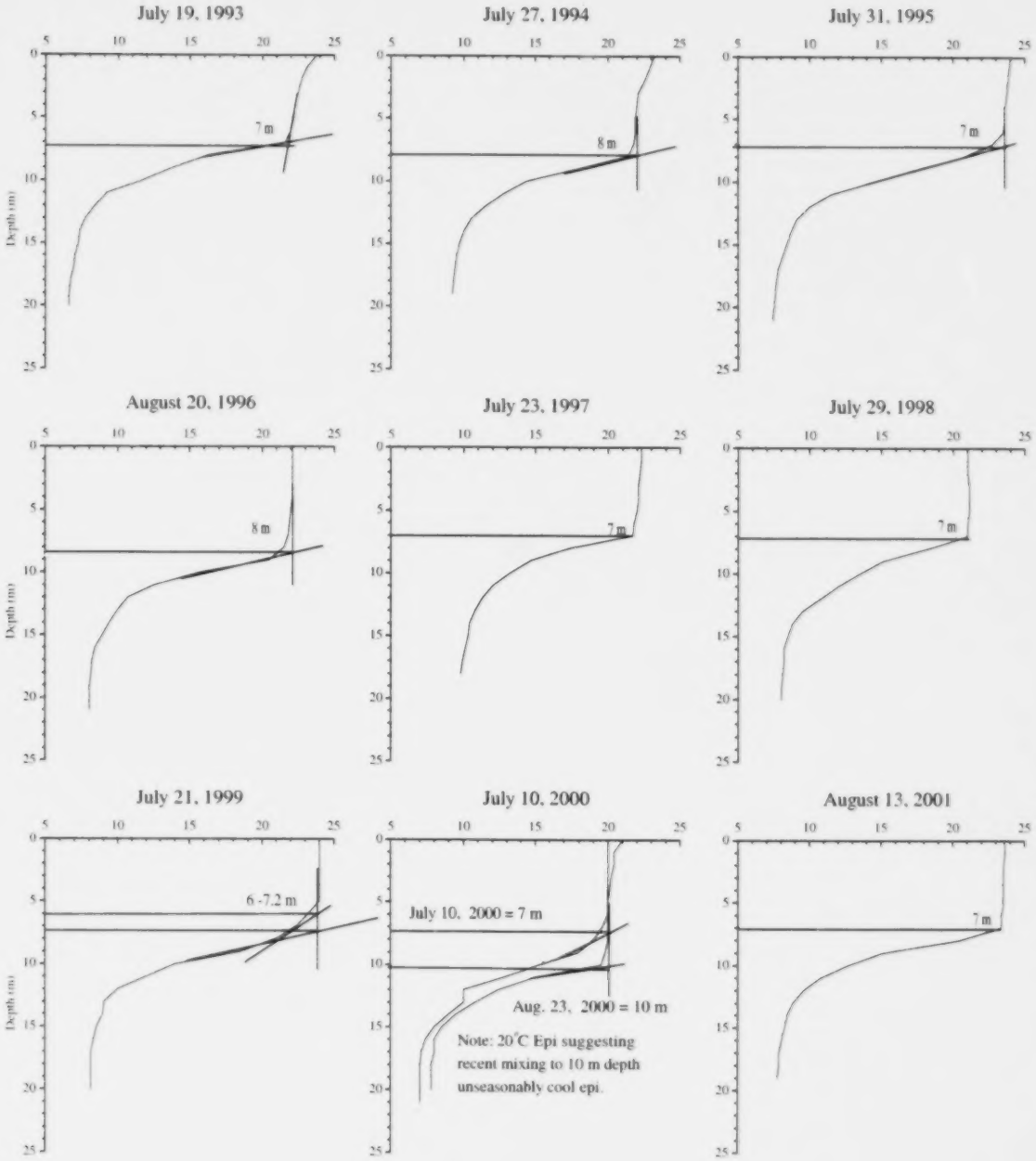
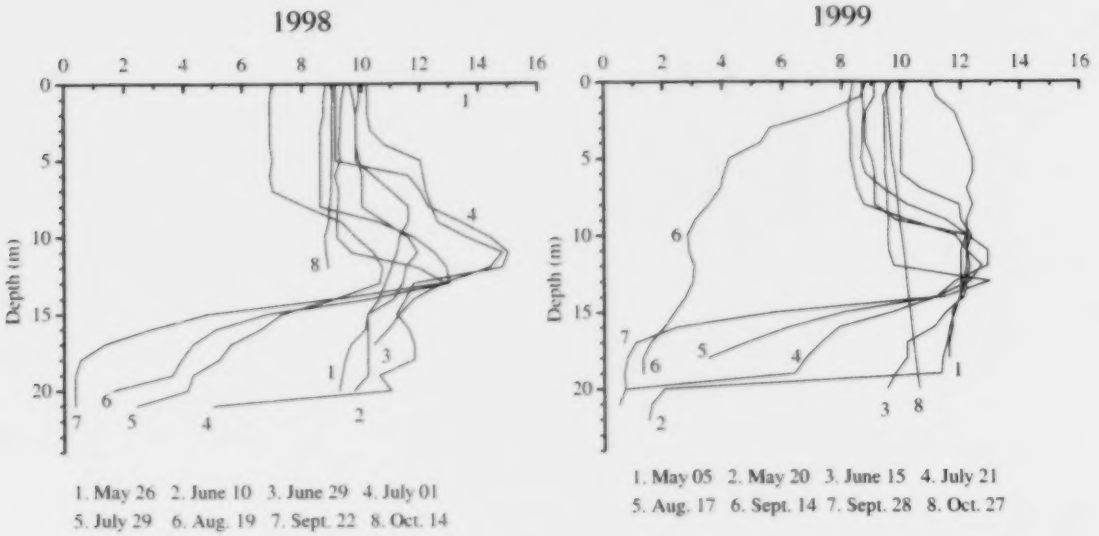


Figure 6j : Clearwater Lake - Recent dissolved oxygen profiles (mg • L^{-1} of O^{2})


1998
1999
Depth (m)
1. May 26 2. June 10 3. June 29 4. July 01
5. July 29 6. Aug. 19 7. Sept. 22 8. Oct. 14
1. May 05 2. May 20 3. June 15 4. July 21
5. Aug. 17 6. Sept. 14 7. Sept. 28 8. Oct. 27

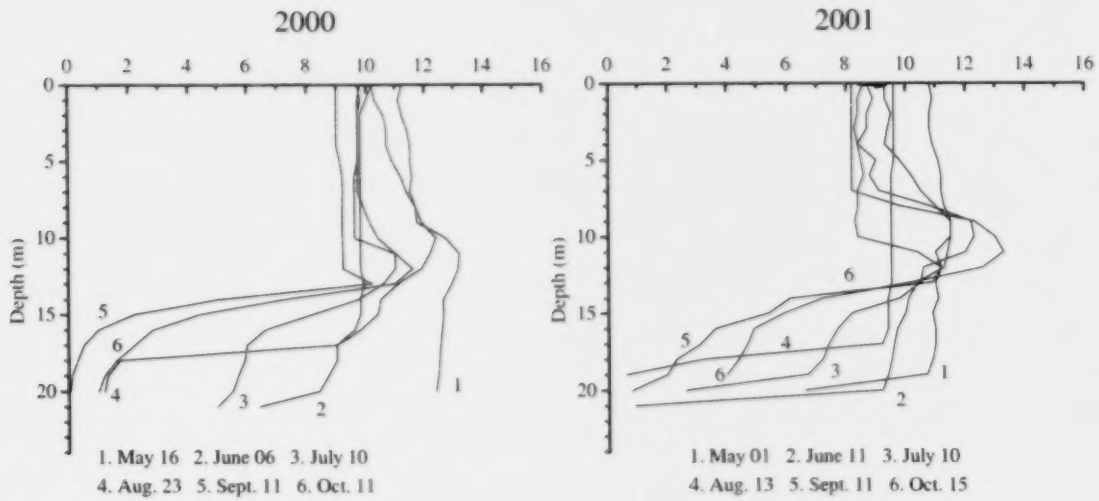


Figure 7. Long-term changes in the limnology of Lohi Lake

7a: Lohi Lake - Base Cations and pH

(* post liming value in 1973, + year of increase in analytical sensitivity)

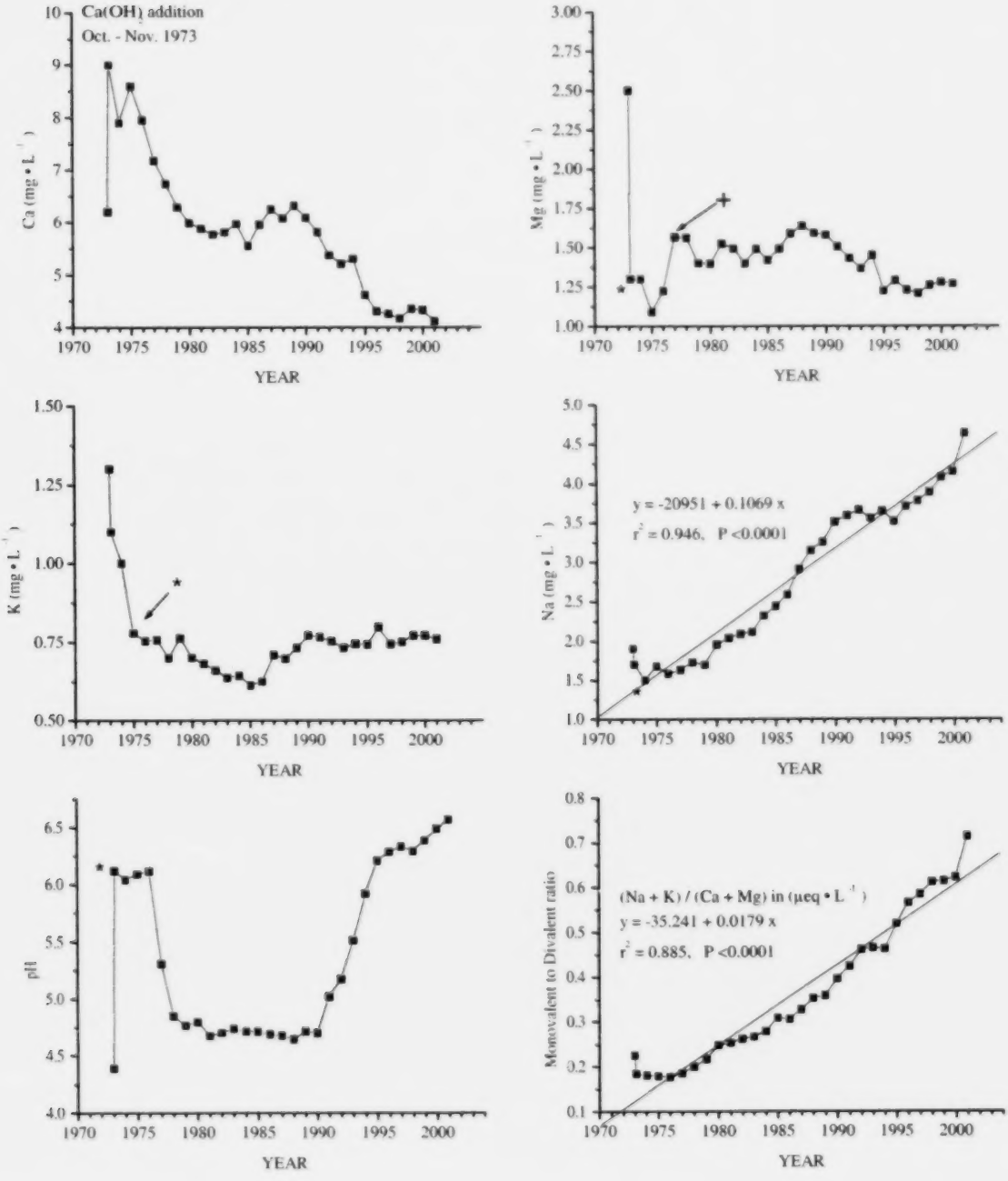

Ca(OH)2 addition
Oct. - Nov. 1973
Ca (mg • L-1)
Mg (mg • L-1)
K (mg • L-1)
Na (mg • L-1)
y = -20951 + 0.1069 x
r2 = 0.946, P <0.0001
pH
(Na + K) / (Ca + Mg) in (μeq • L-1)
y = -35.241 + 0.0179 x
r2 = 0.885, P <0.0001
Monovalent to Divalent ratio
YEAR

Figure 7b: Lohi Lake - Anions & related variables (dissolved inorganic carbon (DIC), alkalinity, conductivity, and a comparison of sums of anions and cations)

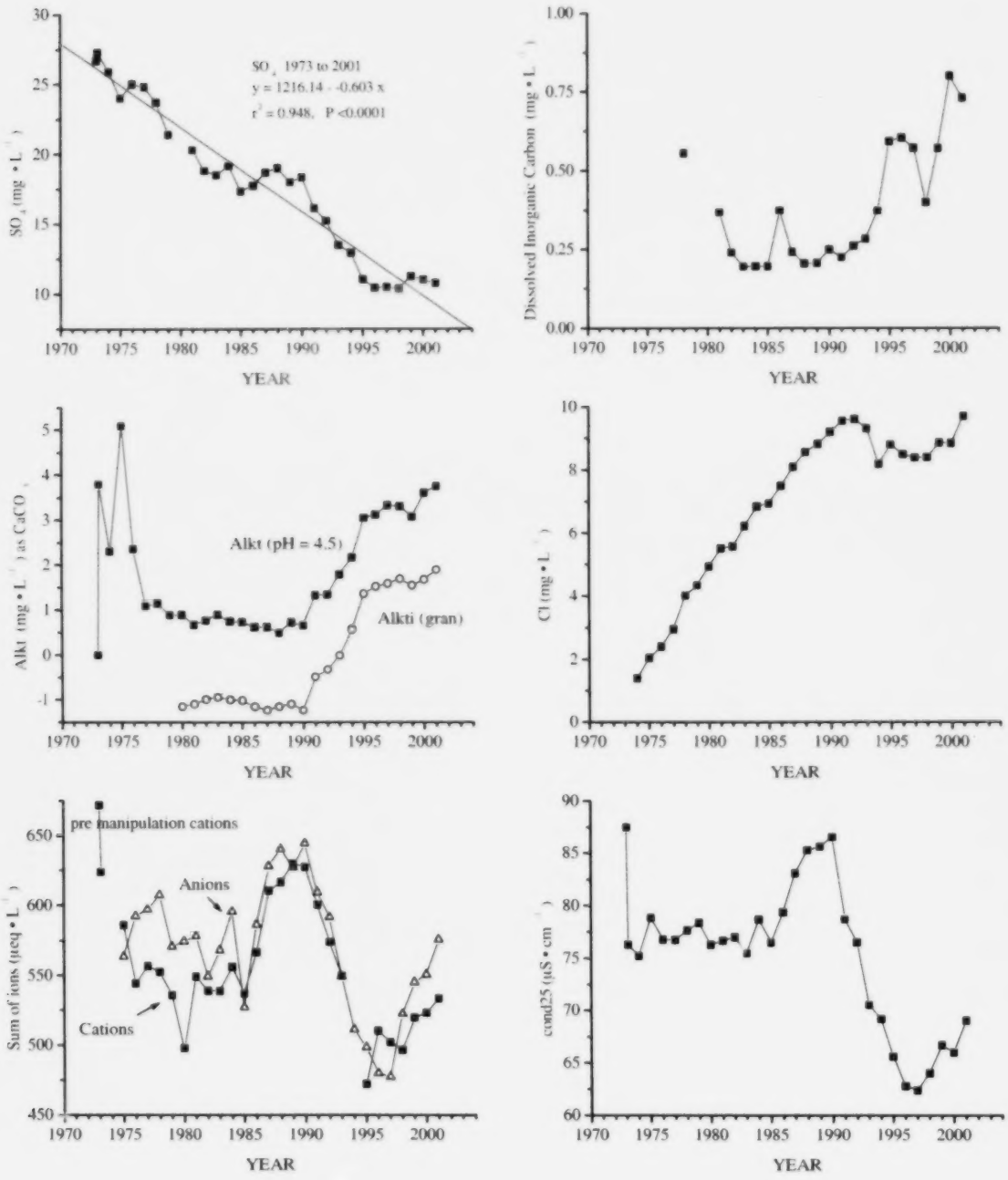


Figure 7c: Lohi Lake - metals (Al, Zn, Cu, Ni, Fe, & Mn)

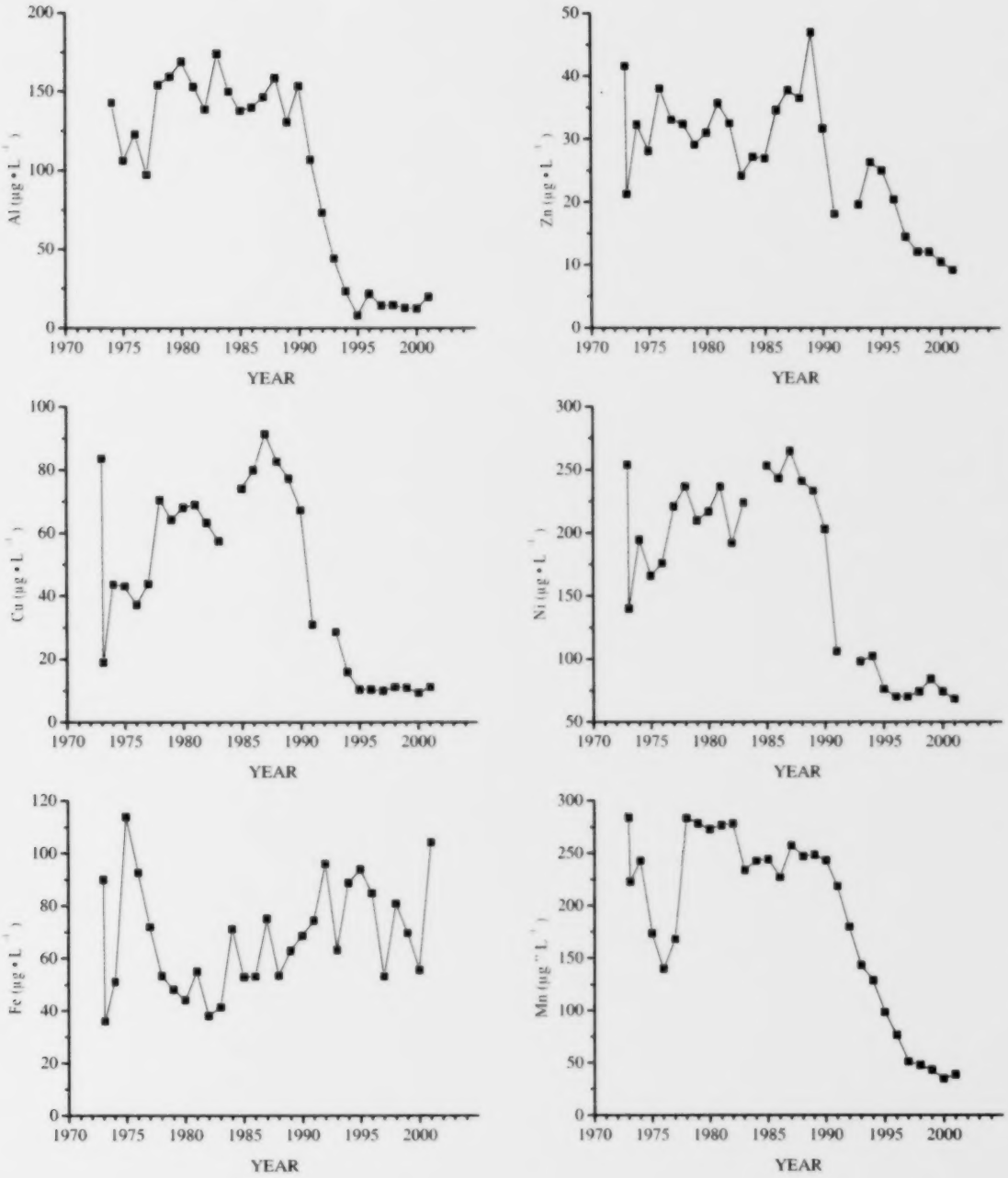


Figure 7d: Lohi Lake - Nitrogen species and TIN/TN ratio

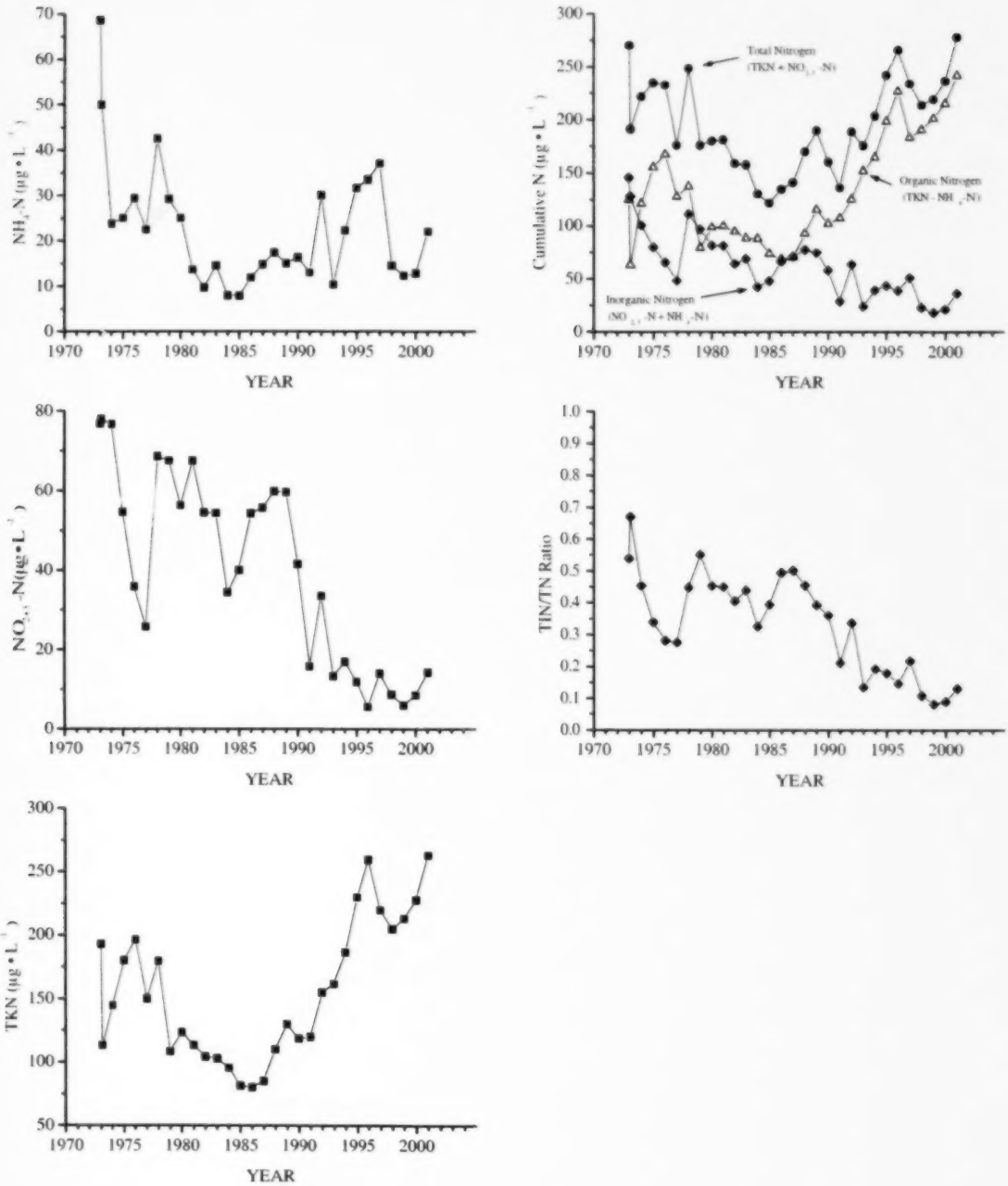


Figure 7e: Lohi Lake - trophic indicators: (chlorophyll, Secchi depth,
dissolved organic carbon, silicate, Total phosphorus, and TN/TP ratio)
(* year TP analysis moved away from sewage plant in Sudbury)

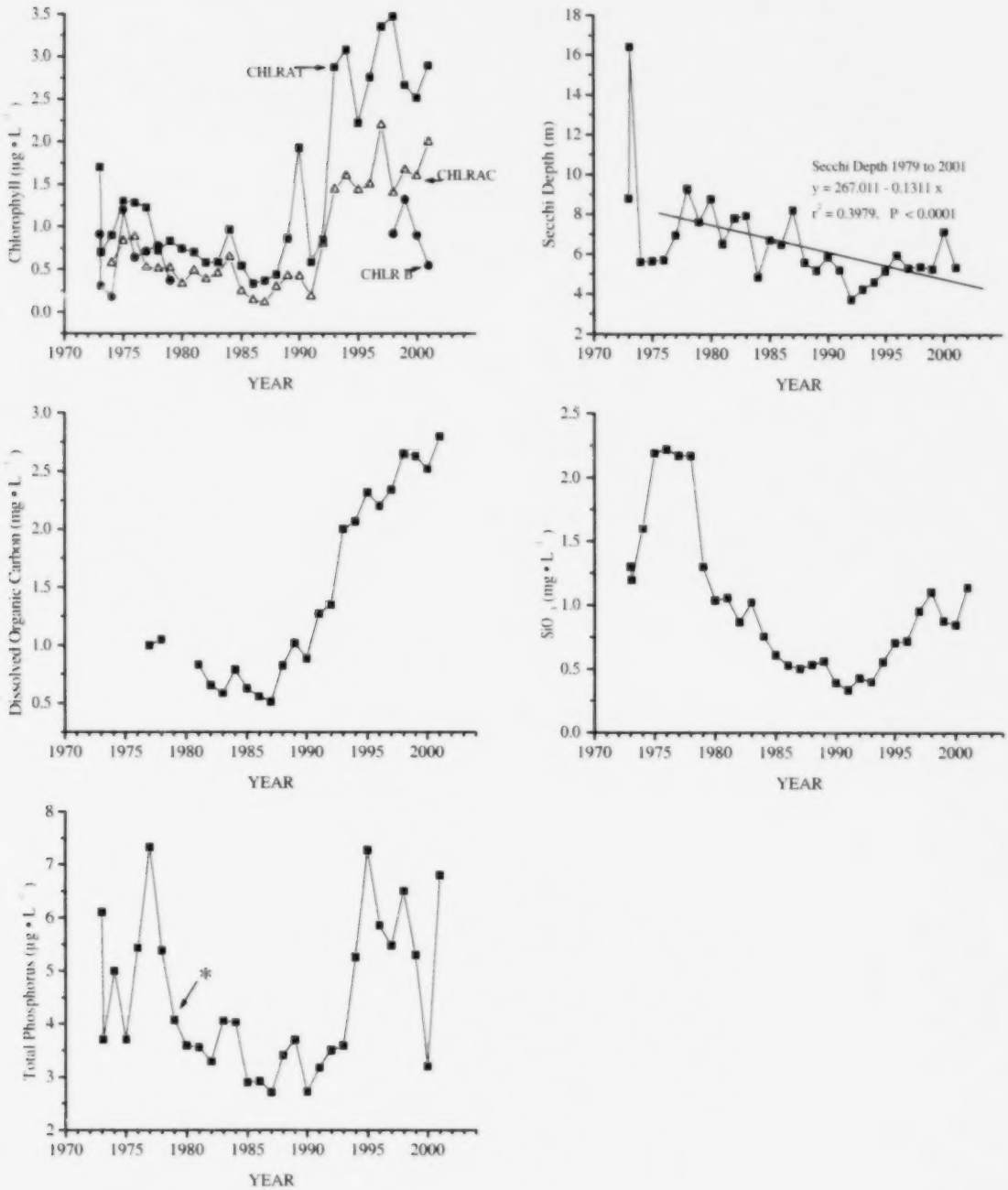


Figure 7f : Lohi Lake changes in thermocline depth and increase in meta + hypolimnetic % total volume, and concurrent changes in mid summer surface and deep water temperatures.

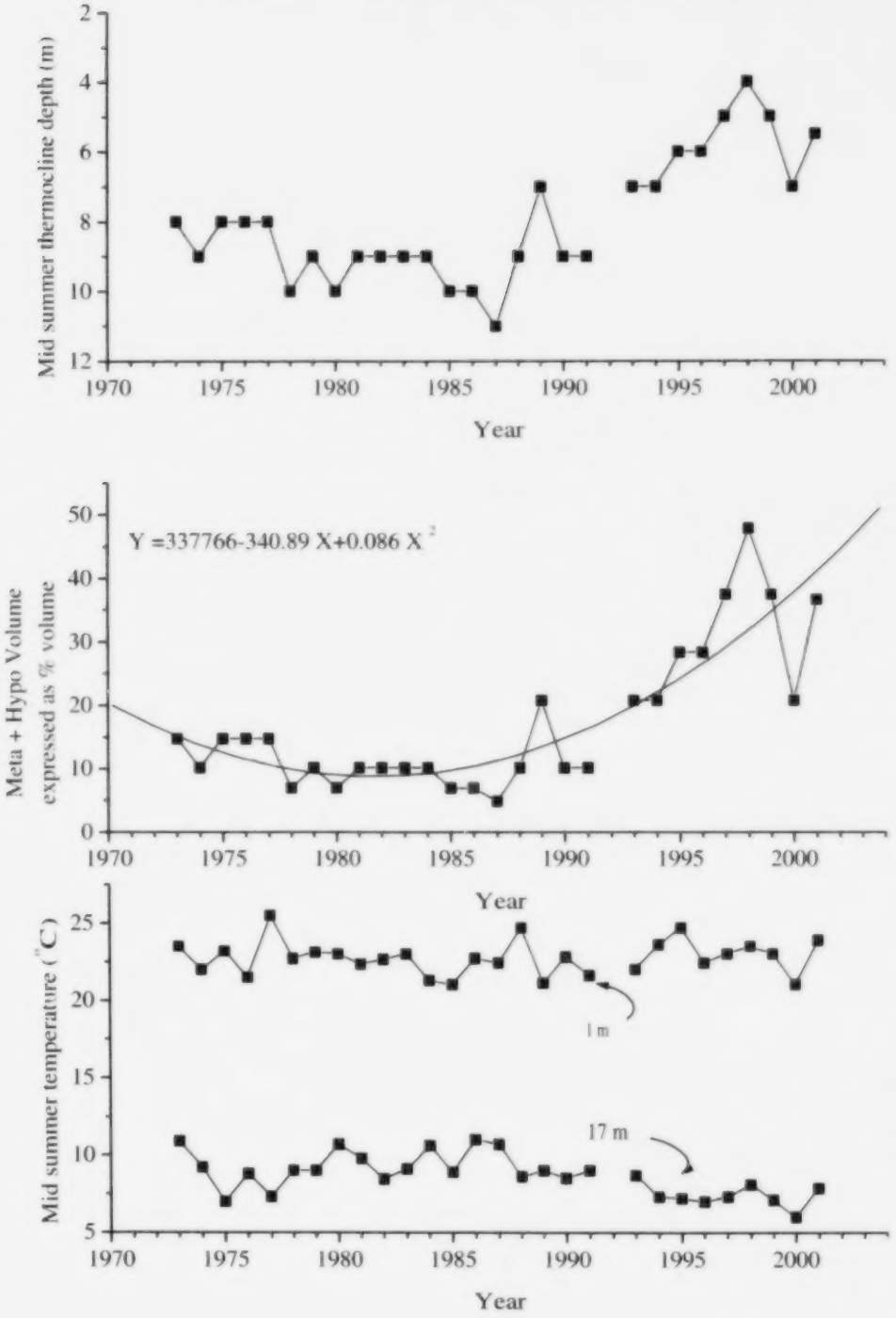
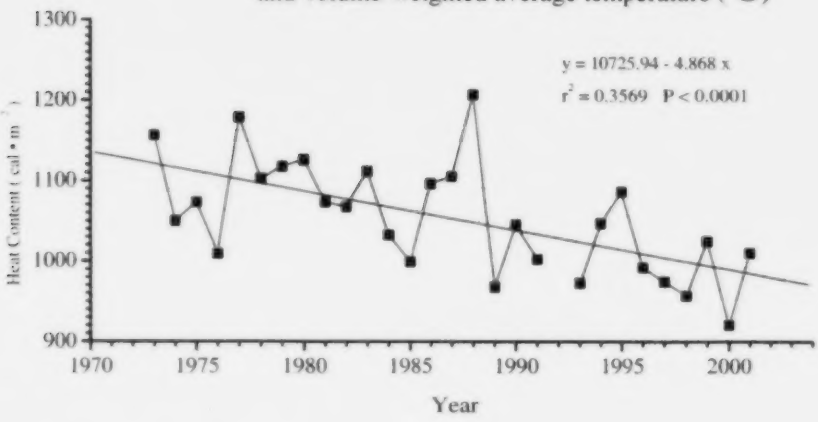
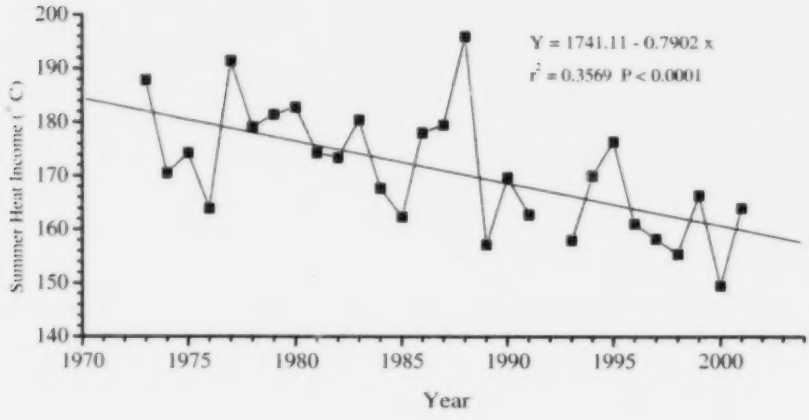


Figure 7g: Lohi Lake changes in maximum heat content (cal • m^{-2}),
maximum summer heat income ($^{\circ}C > 4^{\circ}C$),
and volume-weighted average temperature ($^{\circ}C$)





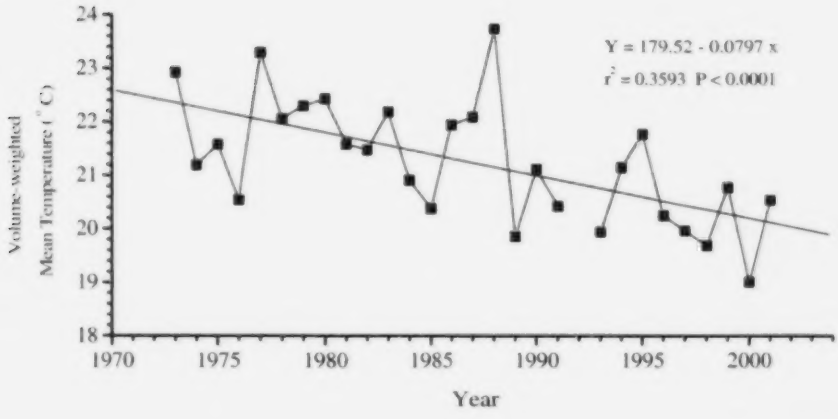
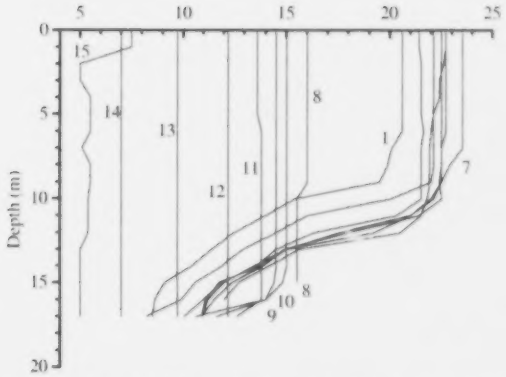


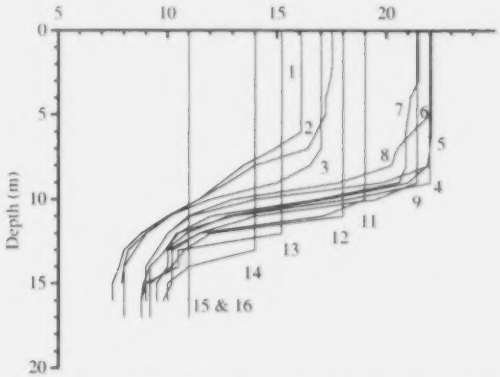
Figure 7h : Lohi Lake - Temperature (°C) Profiles

1973



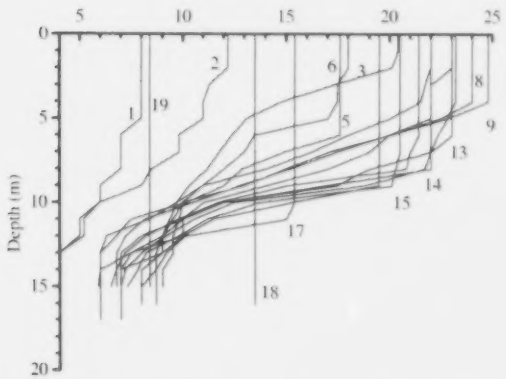
1. June 27 2. July 17 3. Aug. 01 4. Aug. 09 5. Aug. 14 6. Aug. 28
7. Sept. 06 8. Sept. 19 9. Sept. 25 10. Oct. 03 11. Oct. 10 12. Oct. 15
13. Oct. 23 14. Nov. 02 15. Nov. 06

1974



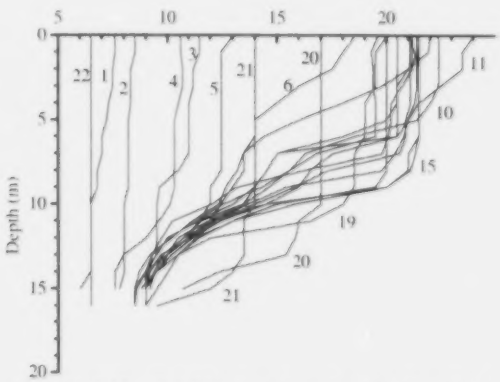
1. June 12 2. June 18 3. June 25 4. July 10 5. July 17 6. July 23
7. Aug. 06 8. Aug. 15 9. Aug. 20 10. Aug. 27 11. Sept. 04
12. Sept. 10 13. Sept. 18 14. Sept. 25 15. Oct. 02 16. Oct. 09

1975



1. May 13 2. May 19 3. May 26 4. June 02 5. June 10 6. June 17
7. June 23 8. July 03 9. July 07 10. July 15 11. July 22 12. July 28
13. Aug. 05 14. Aug. 12 15. Aug. 19 16. Sept. 03 17. Sept. 15
18. Oct. 02 19. Nov. 11

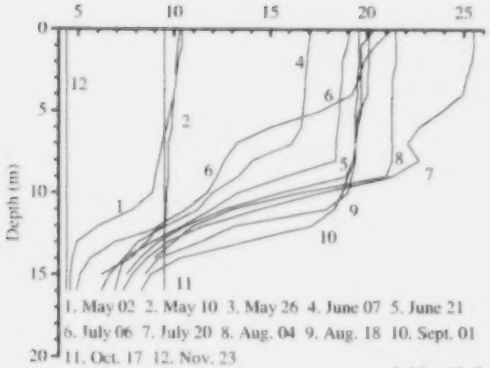
1976



1. Apr. 29 2. May 05 3. May 11 4. May 18 5. May 25 6. May 31
7. June 07 8. June 16 9. June 21 10. June 23 11. July 06
12. July 13 13. July 21 14. July 26 15. Aug. 04 16. Aug. 10
17. Aug. 17 18. Aug. 24 19. Seept. 07 20. Sept. 20 21. Oct. 06
22. Oct. 26

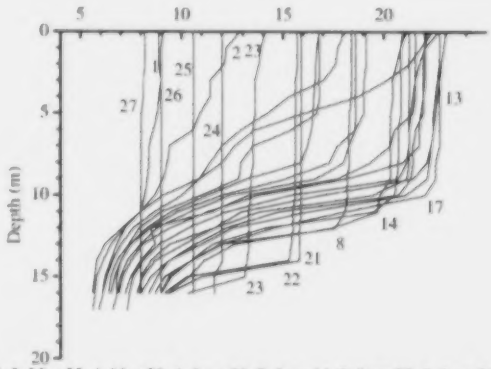
Figure 7h cont'd : Lohi Lake - Temperature (° C) Profiles

1977



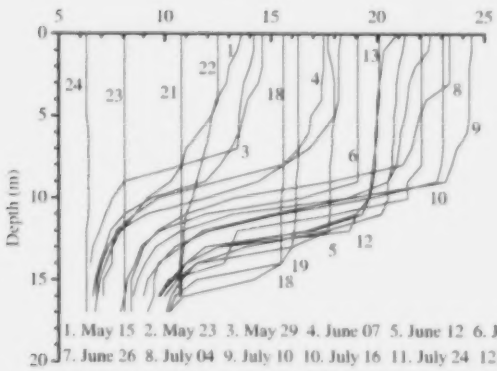
1. May 02 2. May 10 3. May 26 4. June 07 5. June 21
6. July 06 7. July 20 8. Aug. 04 9. Aug. 18 10. Sept. 01
11. Oct. 17 12. Nov. 23

1978



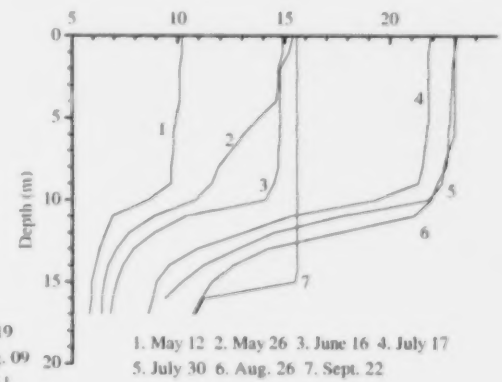
1. May 12 2. May 17 3. May 25 4. May 29 6. June 08 7. June 14 8. June 22 9. June 26
10. July 04 11. July 10 12. July 17 13. July 24 14. July 31 15. Aug. 08 16. Aug. 14
17. Aug. 21 18. Aug. 28 19. Sept. 05 20. Sept. 11 21. Sept. 18 22. Sept. 25 23. Oct. 02
24. Oct. 10 25. Oct. 16 26. Oct. 30 27. Oct. 30

1979



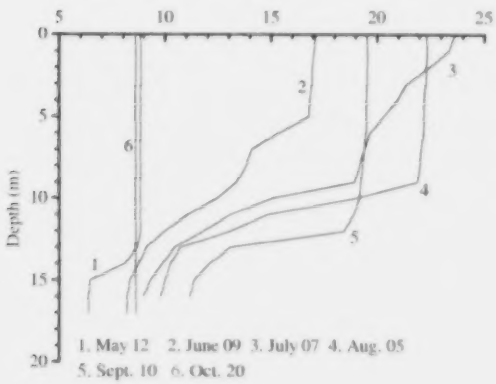
1. May 15 2. May 23 3. May 29 4. June 07 5. June 12 6. June 19
7. June 26 8. July 04 9. July 10 10. July 16 11. July 24 12. Aug. 09
13. Aug. 14 14. Aug. 21 15. Aug. 27 16. Sept. 06 17. Sept. 11
18. Sept. 24 19. Oct. 02 20. Oct. 10 21. Oct. 17 22. Oct. 23 23. Nov. 01
24. Nov.08 25. Nov. 20

1980



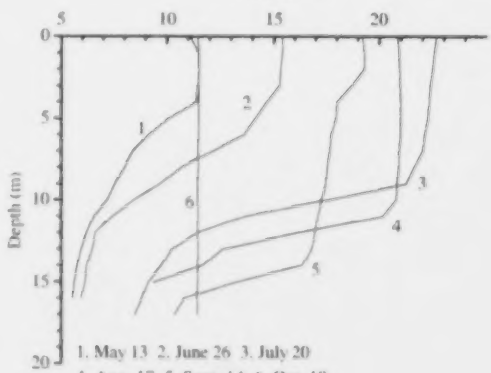
1. May 12 2. May 26 3. June 16 4. July 17
5. July 30 6. Aug. 26 7. Sept. 22

1981



1. May 12 2. June 09 3. July 07 4. Aug. 05
5. Sept. 10 6. Oct. 20

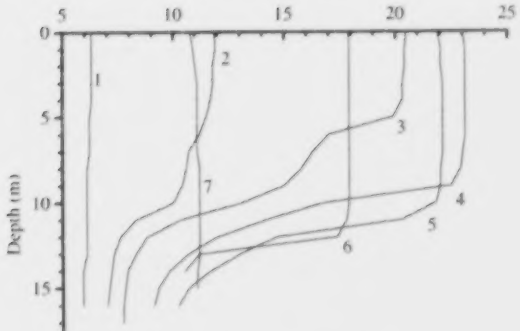
1982



1. May 13 2. June 26 3. July 20
4. Aug. 17 5. Sept. 14 6. Oct. 18

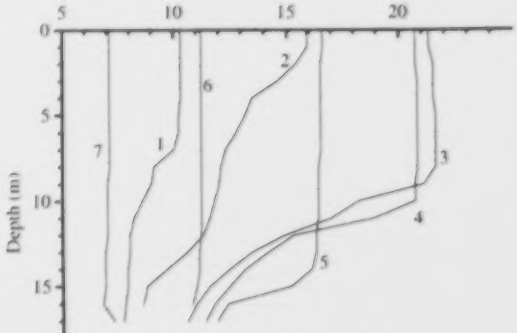
Figure 7h cont'd : Lohi Lake - Temperature (° C) Profiles

1983



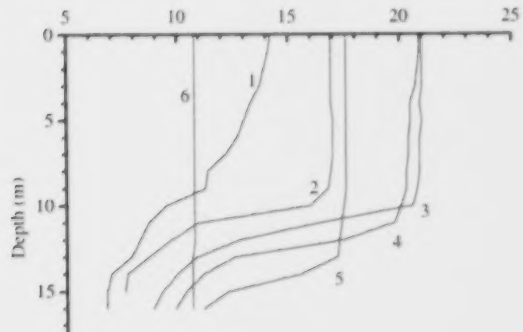
1. May 02 2. May 31 3. June 28 4. July 26
5. Aug. 23 6. Sept. 20 7. Oct. 18

1984



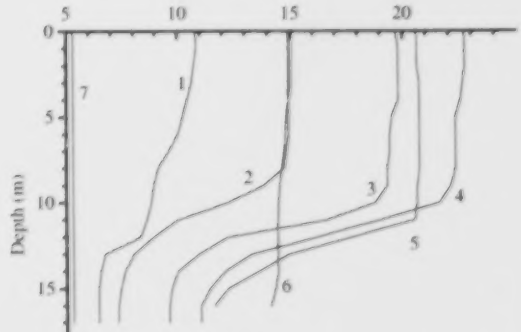
1. May 08 2. June 05 3. July 31 4. Aug. 28
5. Sept. 25 6. Oct. 23 7. Nov. 07

1985



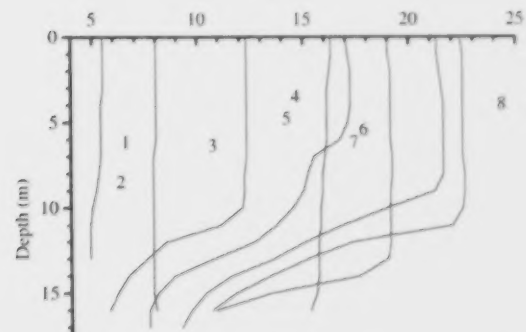
1. May 22 2. June 26 3. July 23 4. Aug. 28
5. Sept,. 24 6. Oct. 22

1986



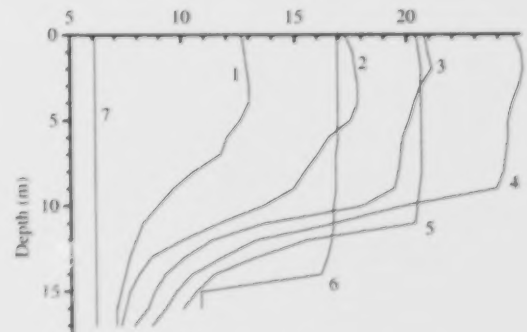
1. May 07 2. June 03 3. July 02 4. July 30
5. Aug. 28 6. Sept. 30 7. Nov. 11

1987



1. Apr. 16 2. May 05 3. June 09 4. July 07
5. Aug. 08 6. Sept. 01 7. Sept. 28 8. Oct. 26

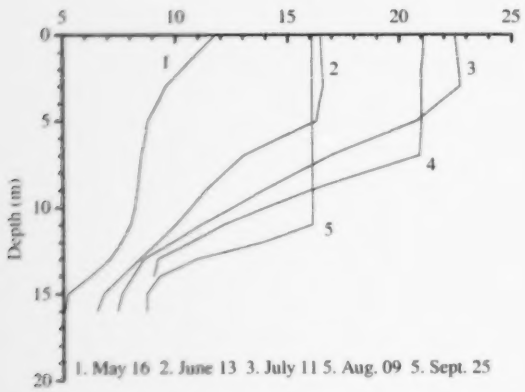
1988



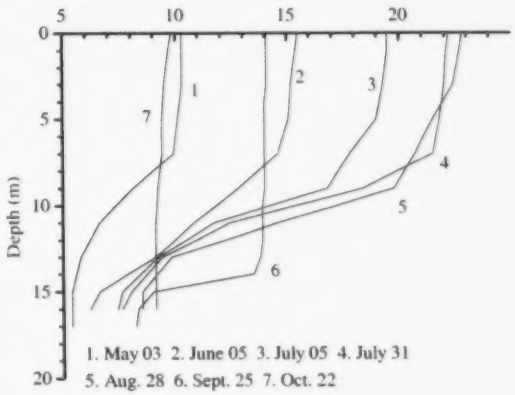
1. May 10 2. June 07 3. July 06 4. Aug. 03
5. Aug. 30 6. Sept 26 7. Nov. 02

Figure 7h cont'd : Lohi Lake - Temperature (^{0} C) Profiles

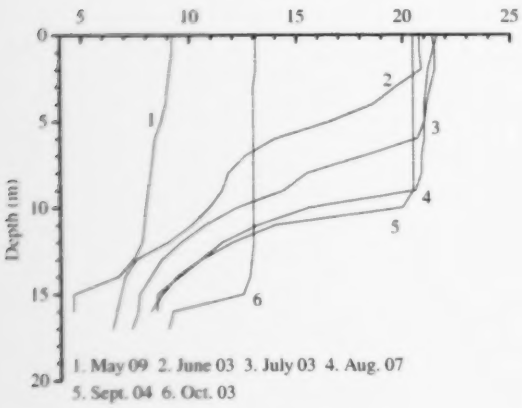
1989



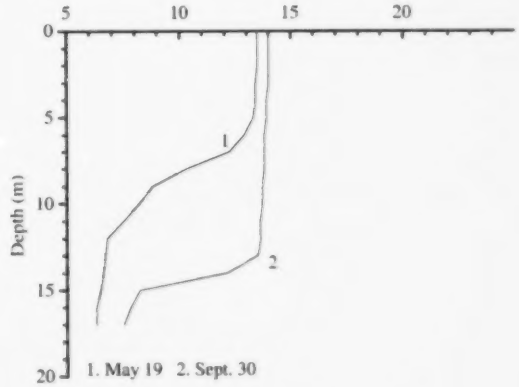
1990



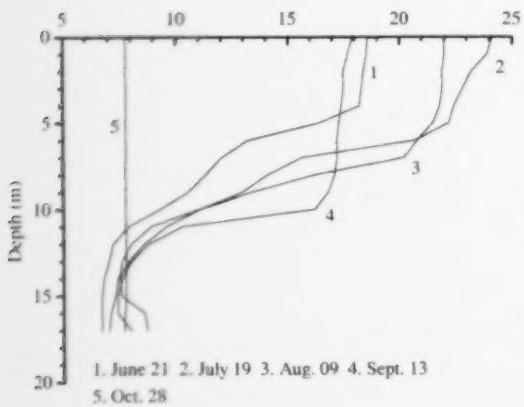
1991



1992



1993



1994

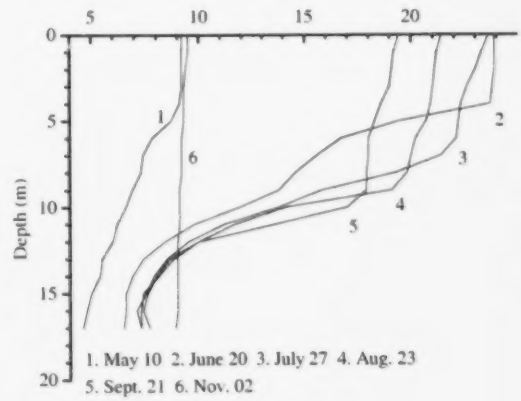


Figure 7h cont'd : Lohi Lake - Temperature (^{0} C) Profiles

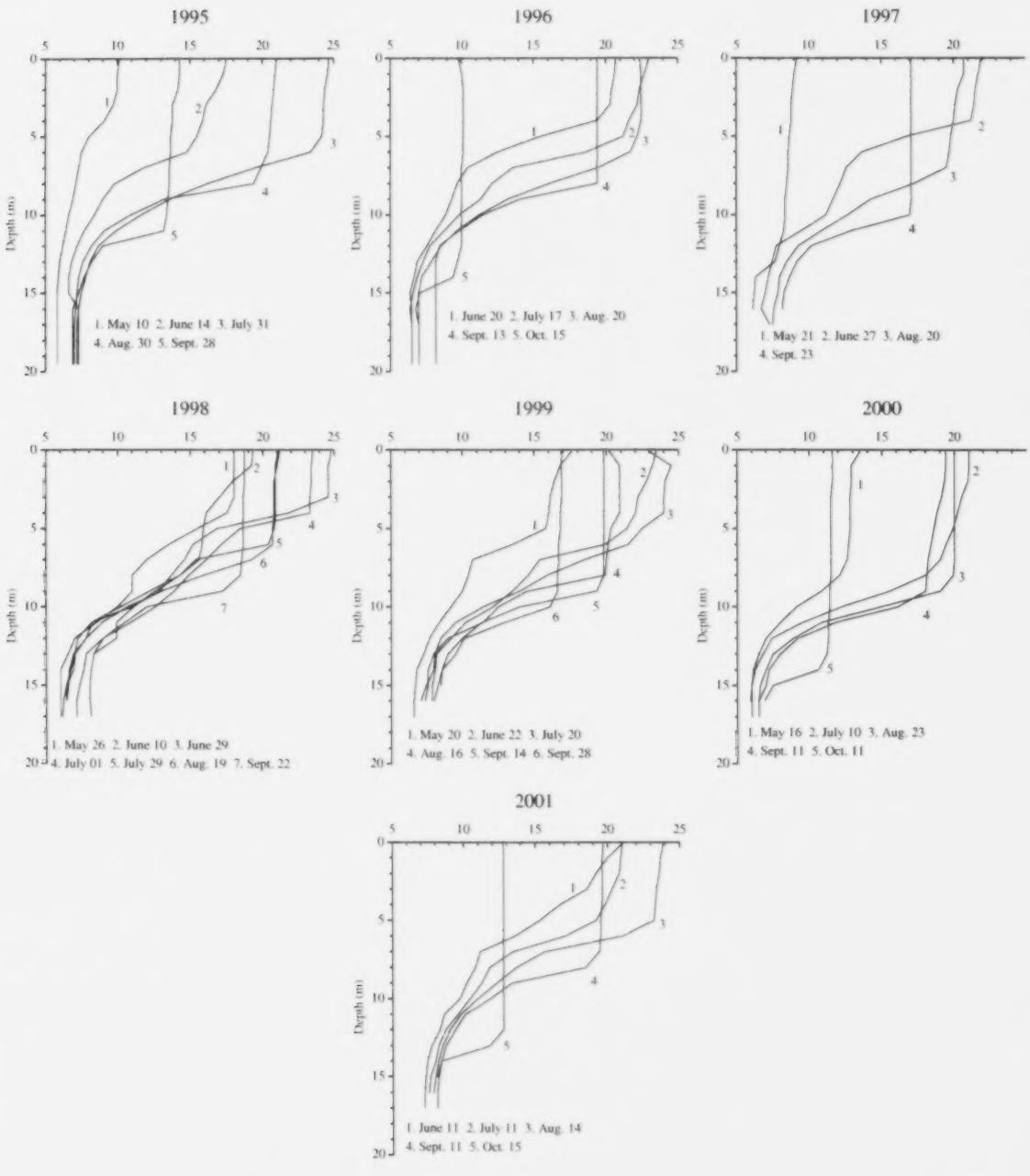


Figure 7i : Lohi Lake epilimnetic depth on the dates of maximum heat content

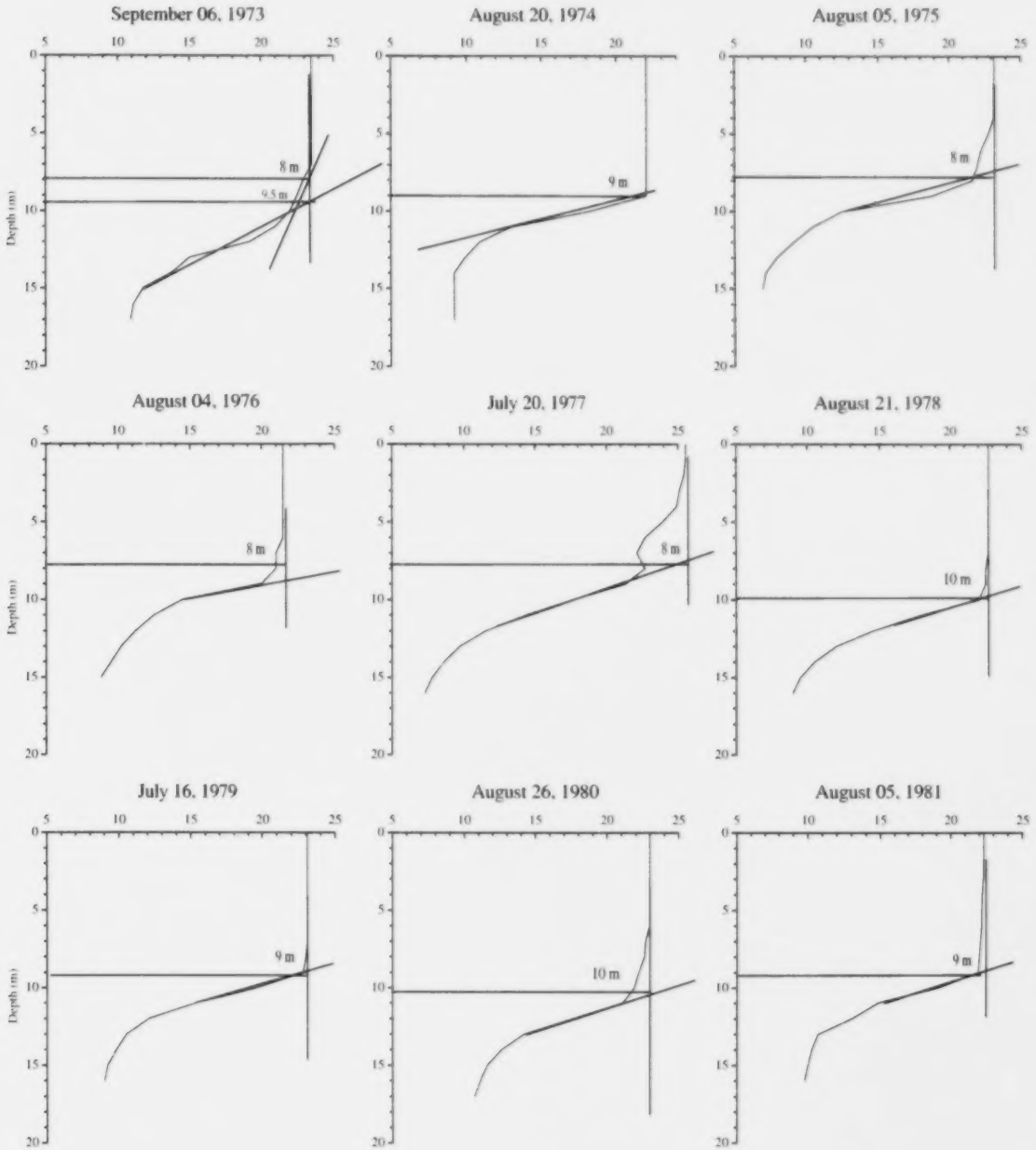


Figure 7i cont'd : Lohi Lake epilimnetic depth on the dates of maximum heat content

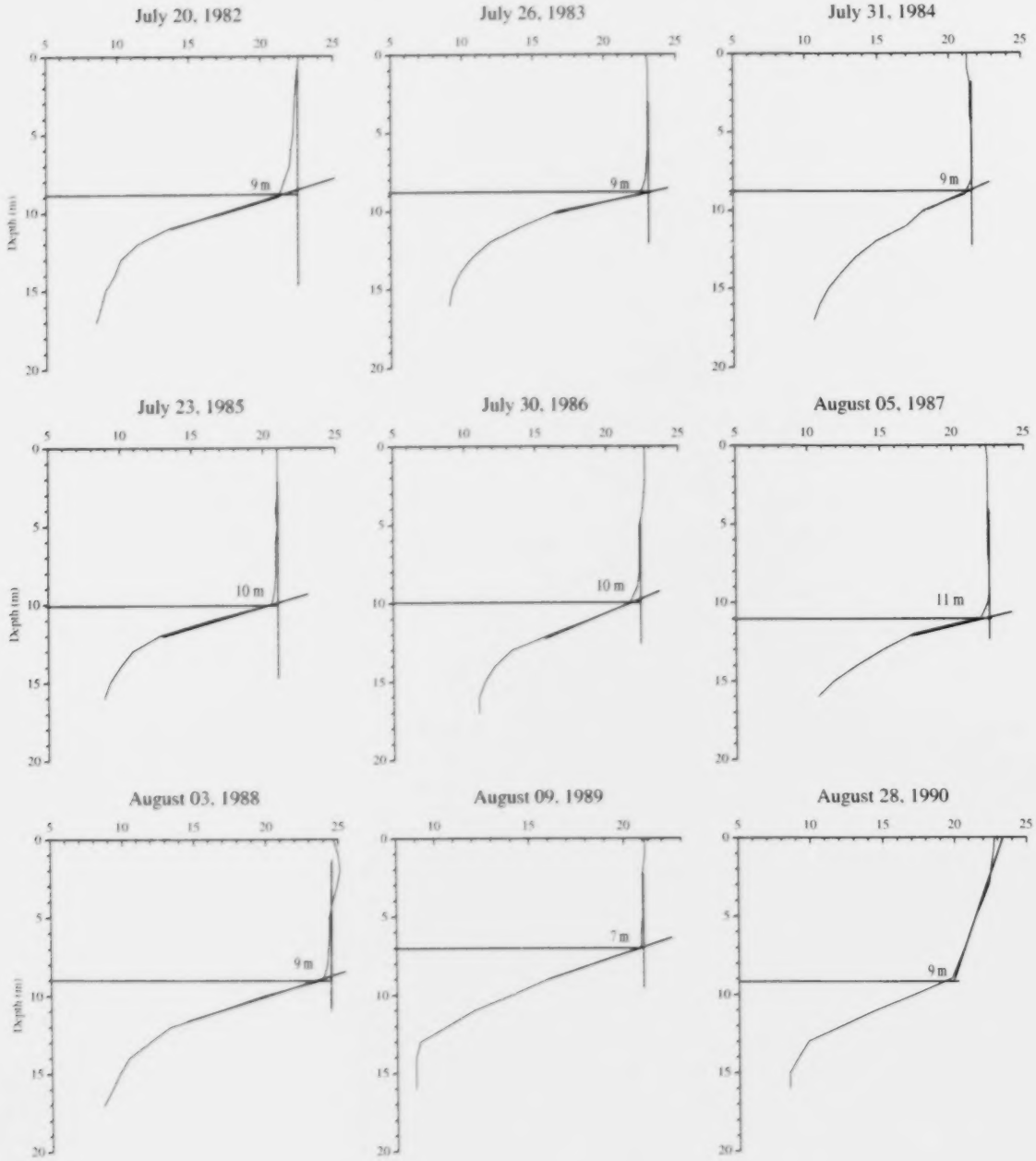


Figure 7i cont'd : Lohi Lake epilimnetic depth on the dates of maximum heat content

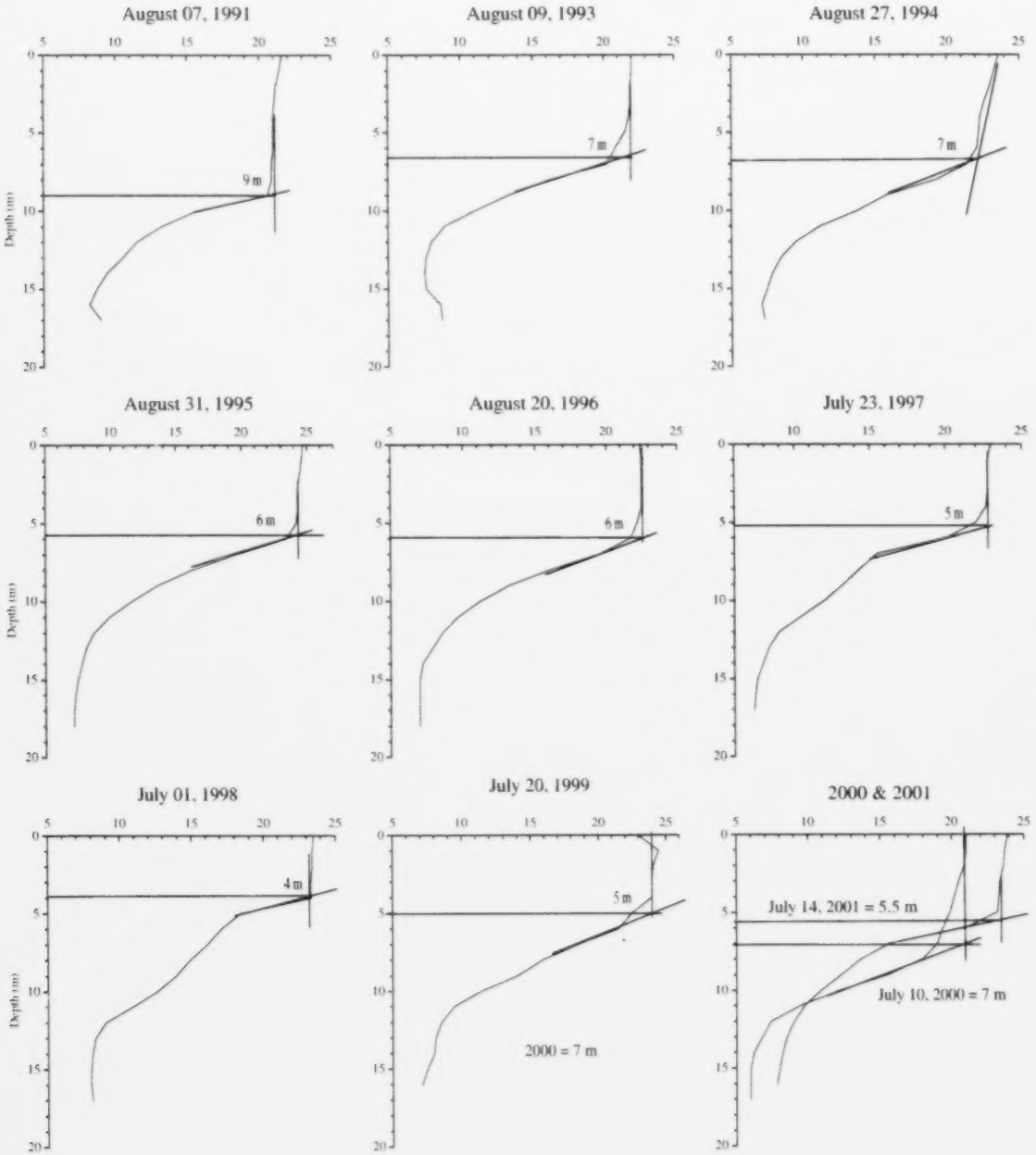


Figure 7j : Lohi Lake - Recent dissolved oxygen (mg • L^{-1} of O^{2})

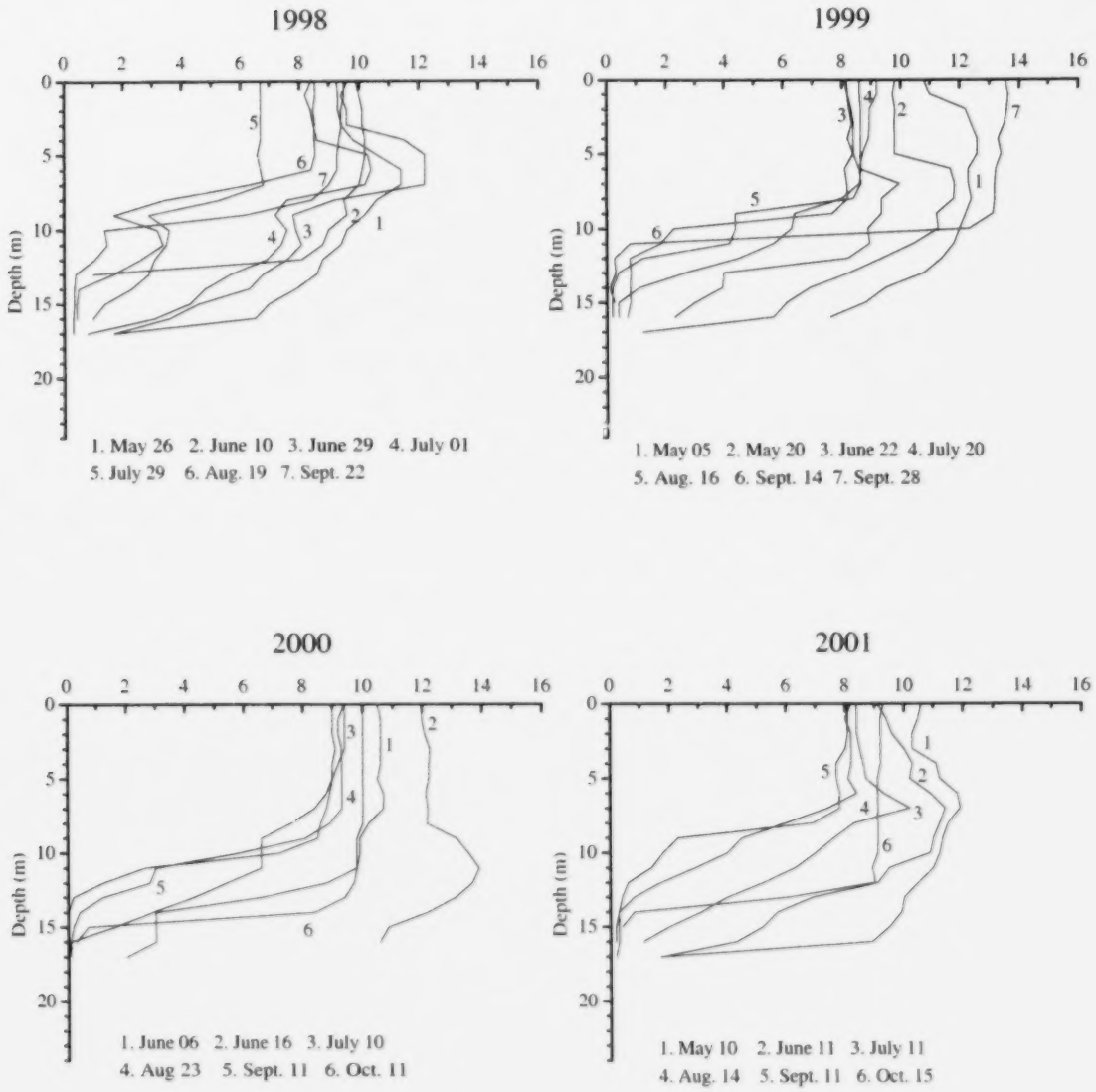

1998
1999
2000
2001
Depth (m)
1. May 26 2. June 10 3. June 29 4. July 01
5. July 29 6. Aug. 19 7. Sept. 22
1. May 05 2. May 20 3. June 22 4. July 20
5. Aug. 16 6. Sept. 14 7. Sept. 28
1. June 06 2. June 16 3. July 10
4. Aug 23 5. Sept. 11 6. Oct. 11
1. May 10 2. June 11 3. July 11
4. Aug. 14 5. Sept. 11 6. Oct. 15

Figure 8. Long-term changes in the limnology of Middle Lake

8a : Middle Lake - Base cations and pH (Ca, Mg, K, Na, pH & Monovalent to Divalent ratio)

* year of increase in analytical sensitivity

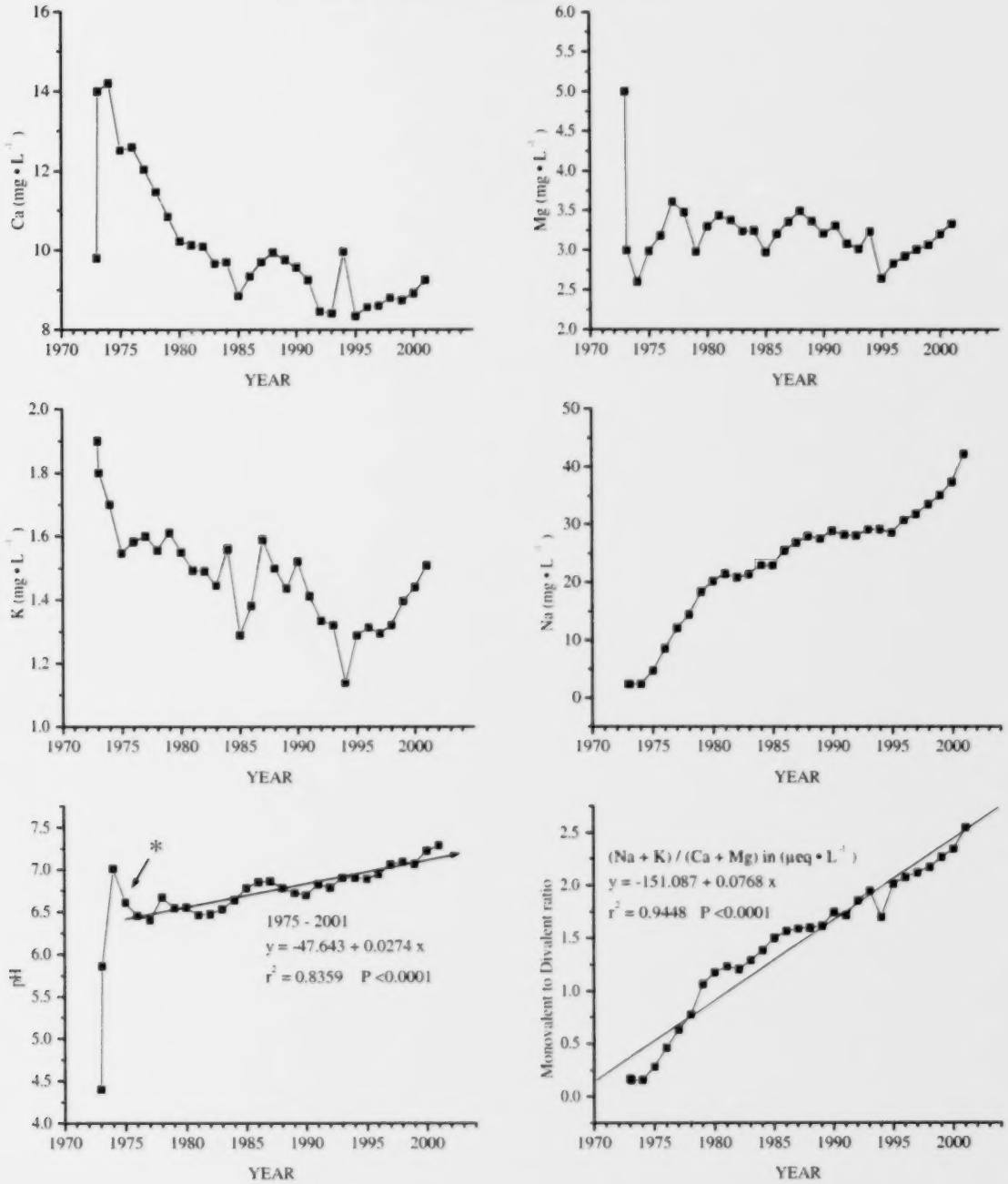

Ca (mg • L⁻¹)
Mg (mg • L⁻¹)
K (mg • L⁻¹)
Na (mg • L⁻¹)
pH
Monovalent to Divalent ratio
YEAR
*
1975 - 2001
y = -47.643 + 0.0274 x
r² = 0.8359 P <0.0001
(Na + K) / (Ca + Mg) in (μeq • L⁻¹)
y = -151.087 + 0.0768 x
r² = 0.9448 P <0.0001

Figure 8b: Middle Lake - Anions & related variables : (dissolved inorganic carbon (DIC), alkalinity, and conductivity, and a comparison of sums of anions and cations)

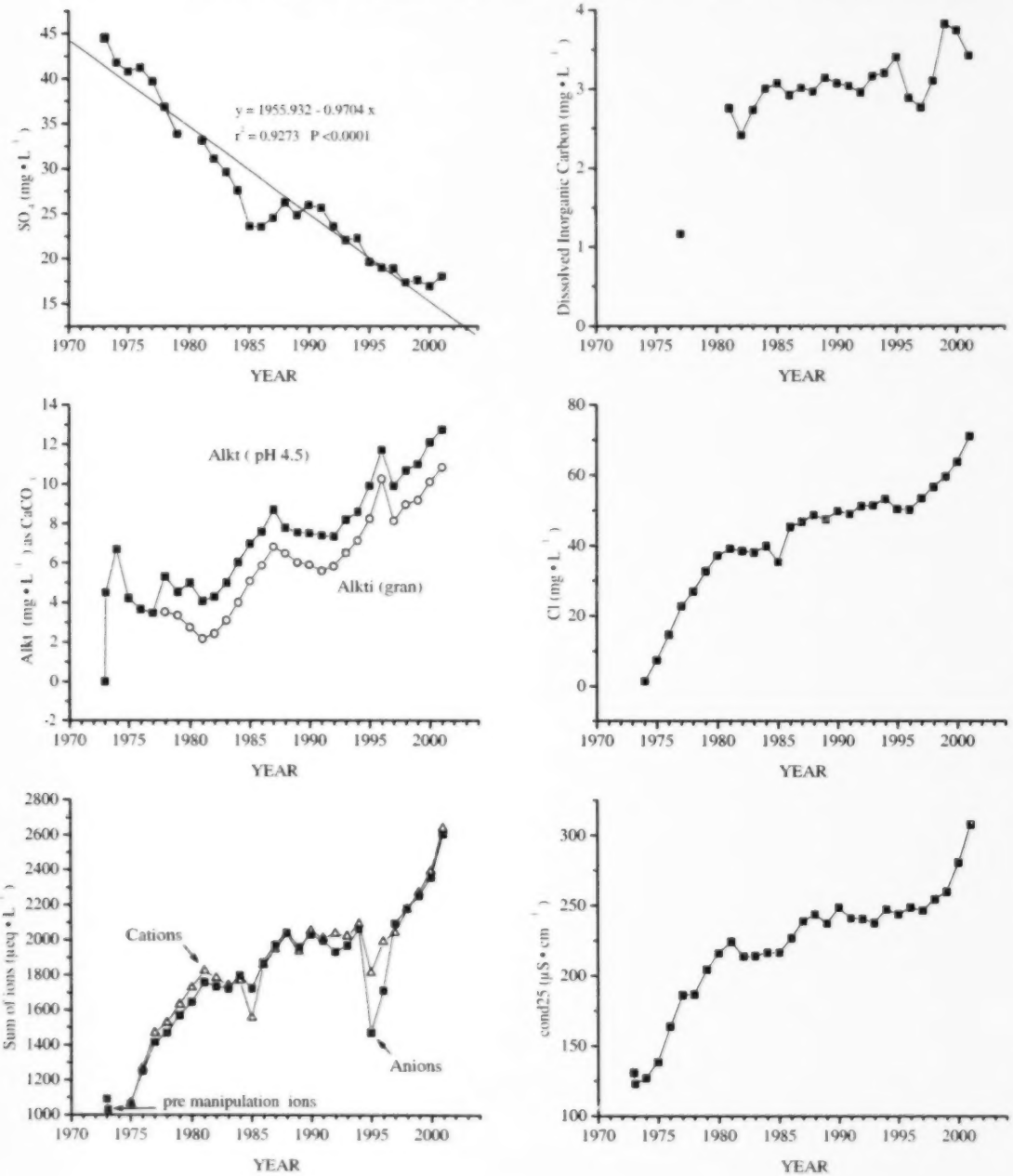


Figure 8c : Middle Lake - metals : (Al, Zn, Cu, Ni, Fe, & Mn)

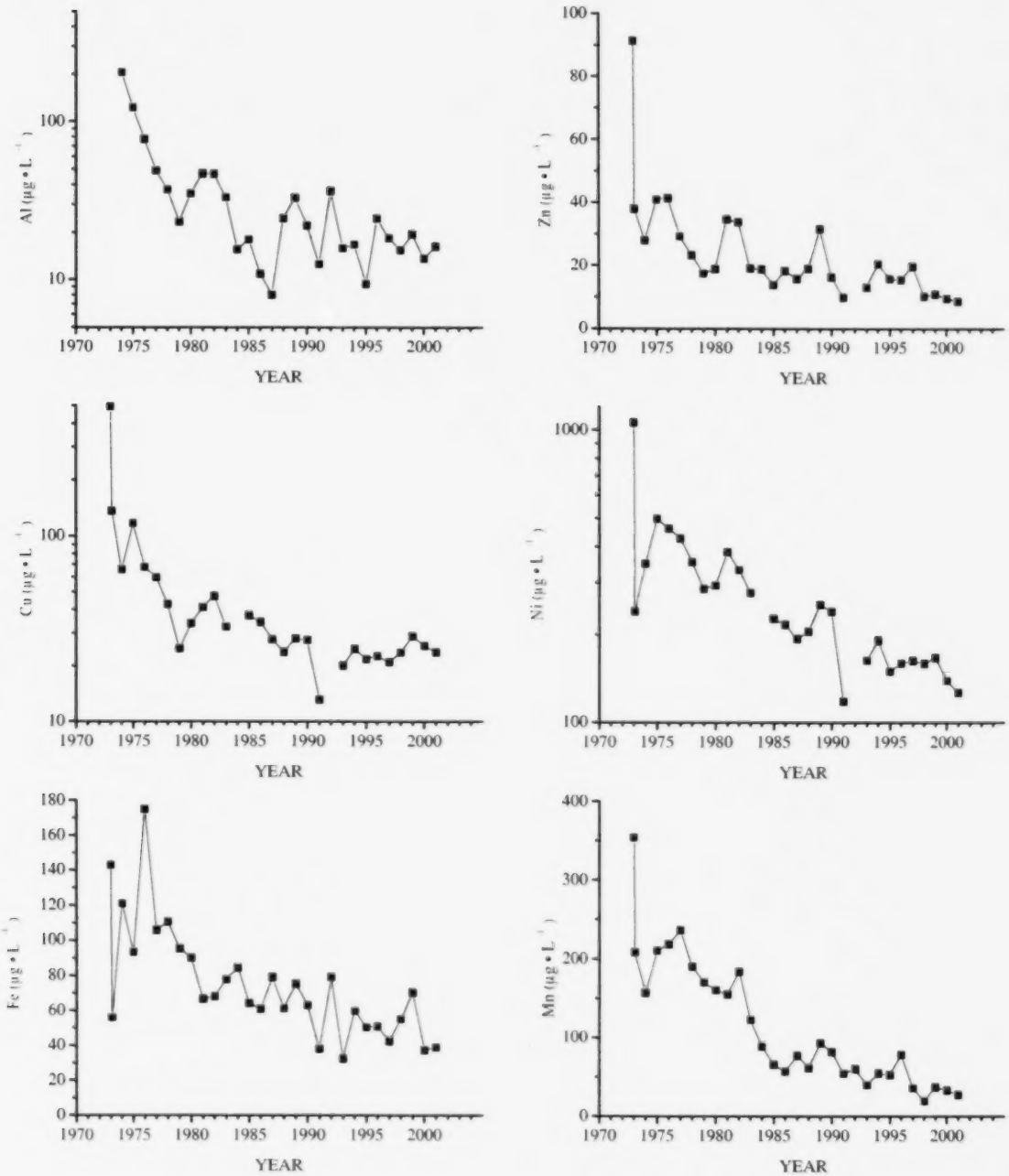


Figure 8d : Middle Lake - Nitrogen species and TIN / TN ratio

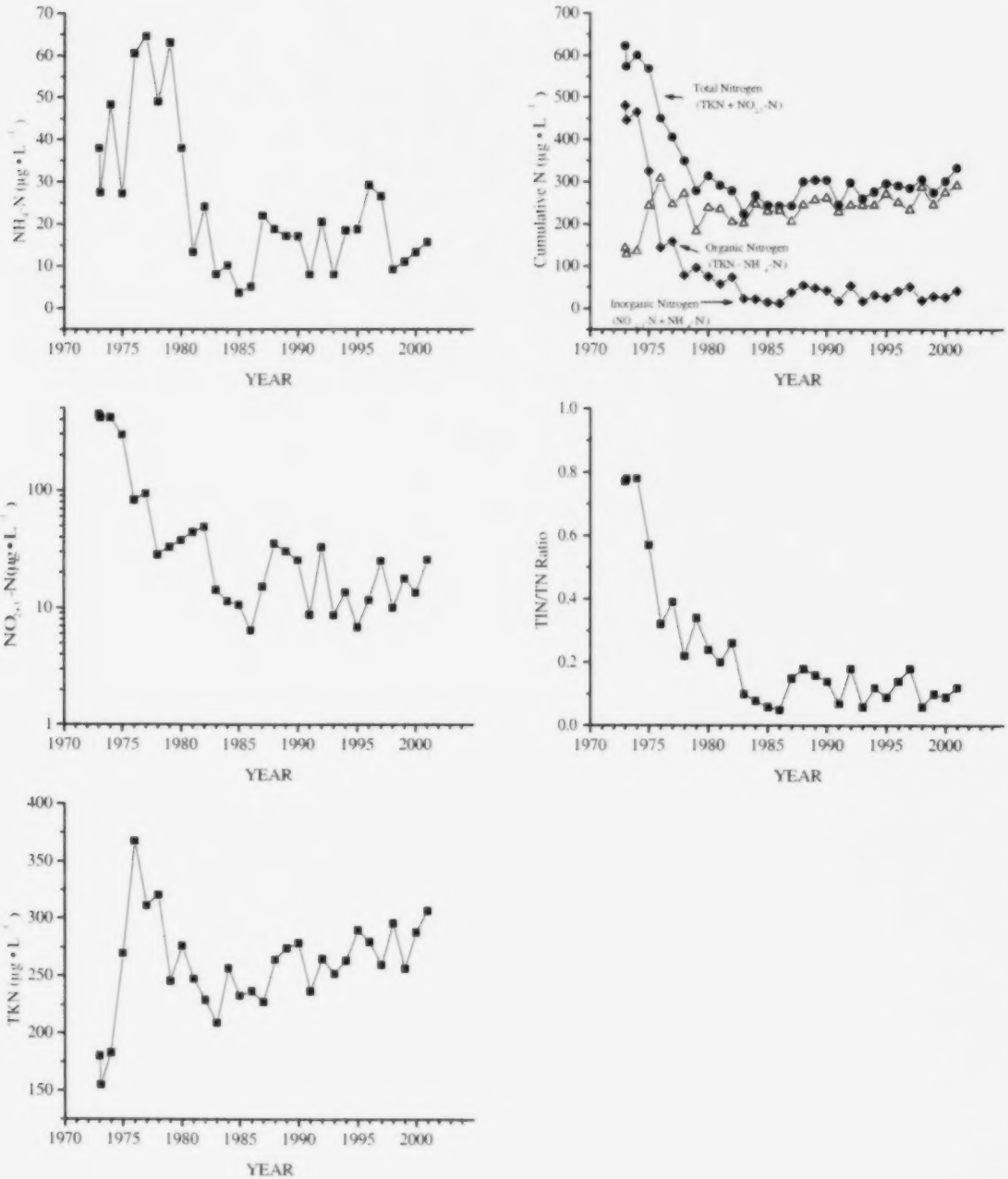


Figure 8e: Middle Lake - trophic indicators : (chlorophyll, Secchi depth, dissolved organic carbon (DOC), silicate, Total phosphorus, and TN/TP ratio) (* year TP analysis moved away from sewage plant in Sudbury)

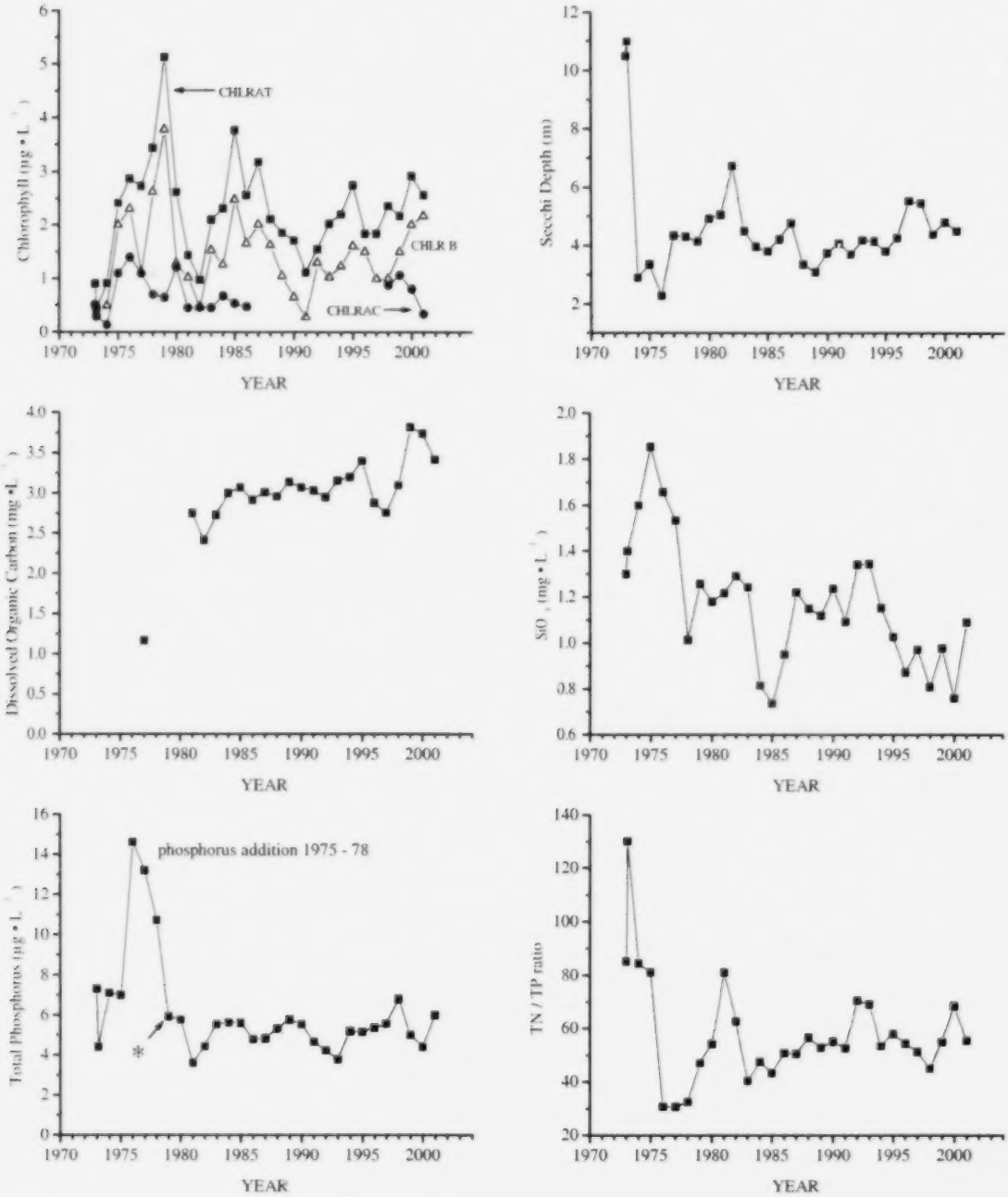
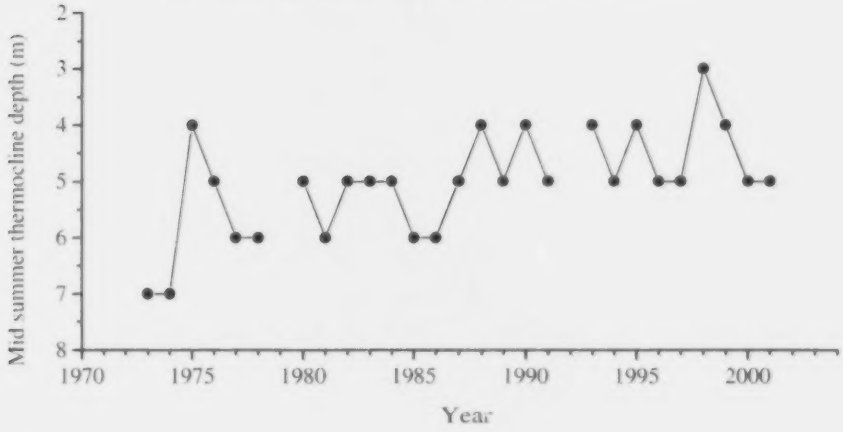
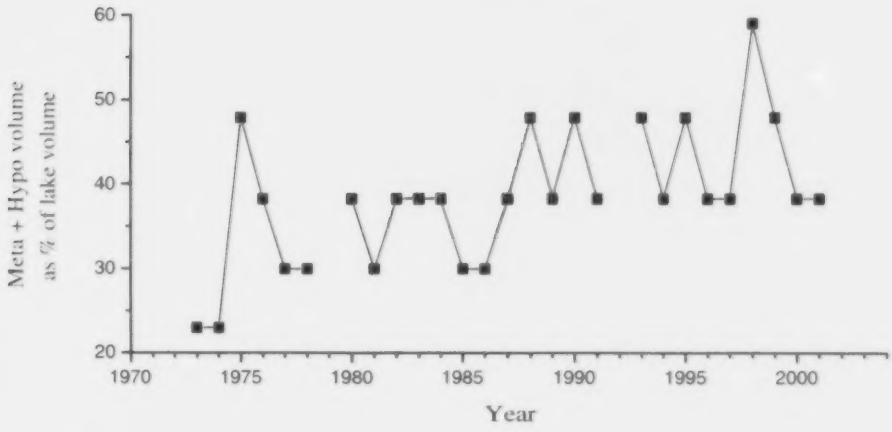


Figure 8f : Middle Lake changes in thermocline depth and increase in meta + hypolimnetic % total volume, and concurrent changes in mid summer surface and deep water temeratures.





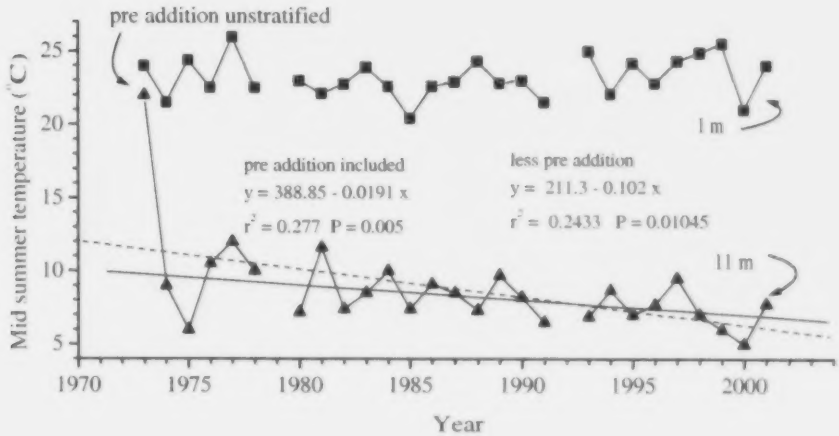


Figure 8g. Middle Lake changes in maximum heat content (cal • m ^{2}),
maximum summer heat income (^{o} C >4 ^{o} C),
and volume-weighted average temperature (^{o} C)

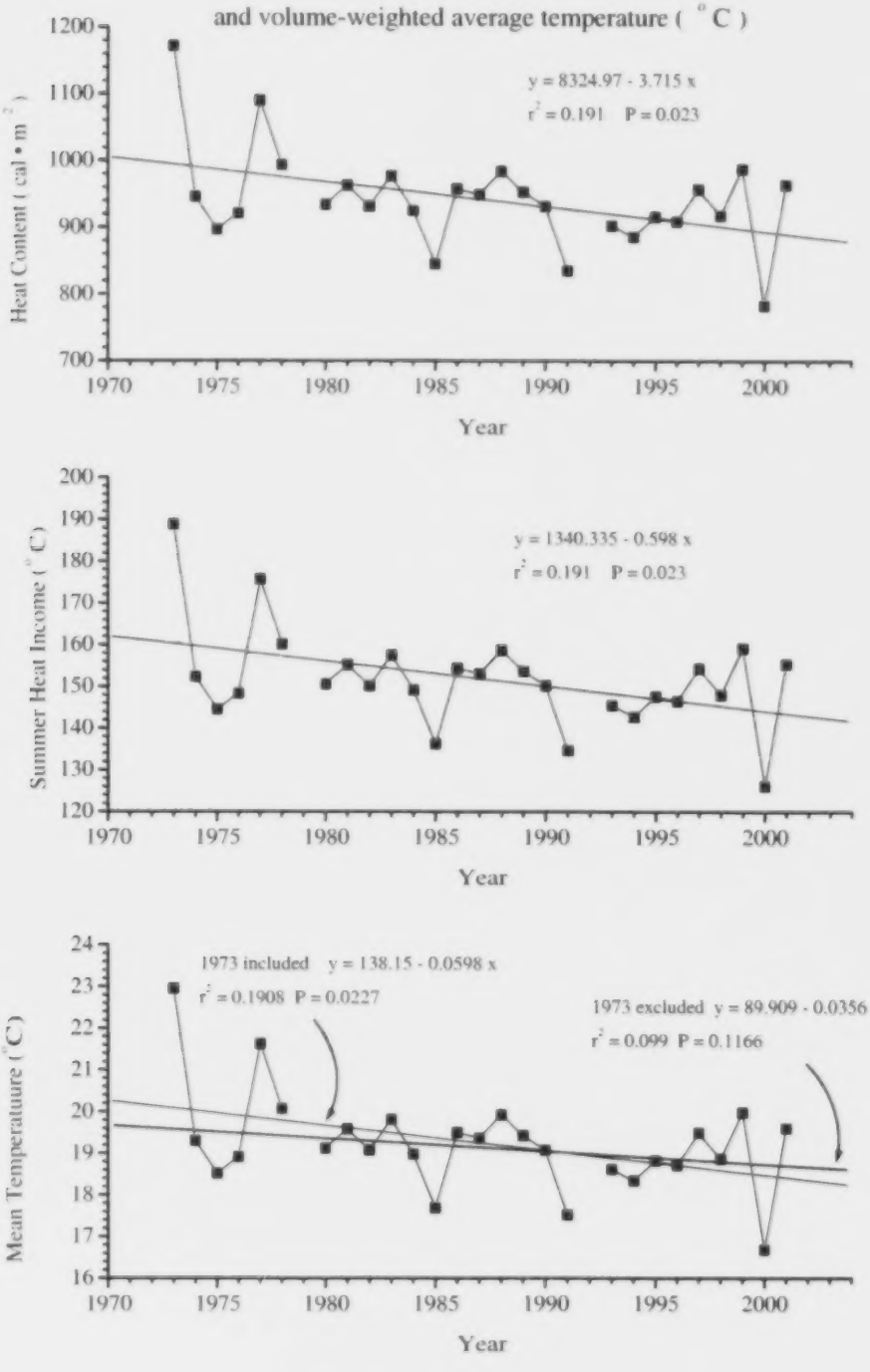
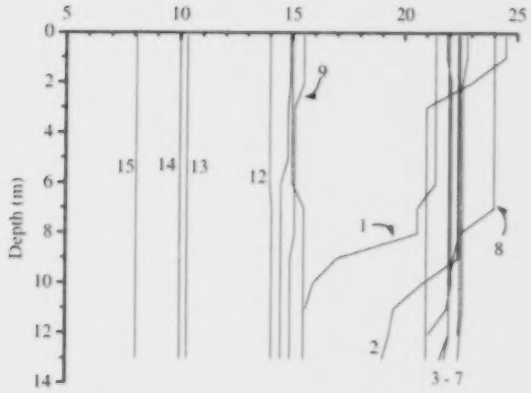

Heat Content (cal • m ^{2})
y = 8324.97 - 3.715 x
r^2 = 0.191 P = 0.023
Year
Summer Heat Income (^{o} C)
y = 1340.335 - 0.598 x
r^2 = 0.191 P = 0.023
Year
Volume - Weighted
Mean Temperatuure (^{o} C)
1973 included y = 138.15 - 0.0598 x
r^2 = 0.1908 P = 0.0227
1973 excluded y = 89.909 - 0.0356 x
r^2 = 0.099 P = 0.1166
Year

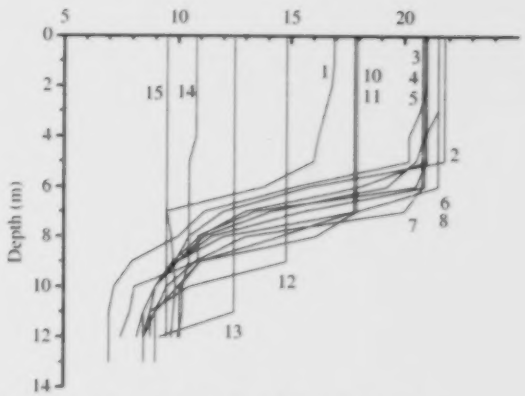
Figure 8h. Middle Lake - Temperature (°C) Profiles

1973



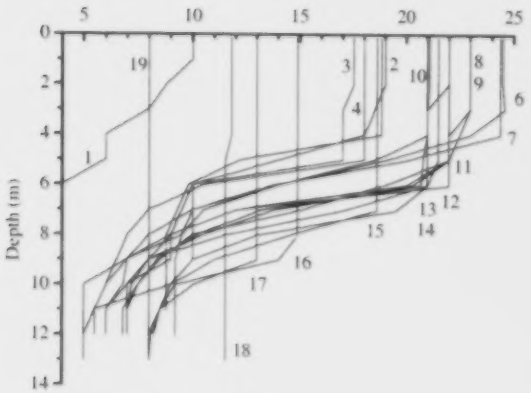
1. June 28 2. July 19 3. July 31 4. Aug. 08 5. Aug. 13
6. Aug. 20 7. Aug. 27 8. Sept. 05 9. Sept. 18 10. Sept. 27
11. Oct. 01 12. Oct. 09 13. Oct.. 18 14. Oct. 22 15. Nov. 01

1974



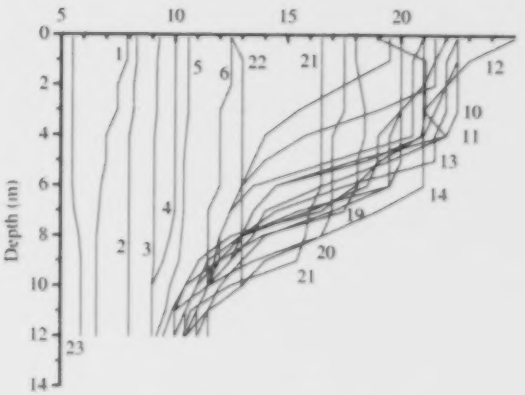
1. June 18 2. July 10 3. July 17 4. July 23 5. July 30
6. Aug. 06 7. Aug. 15 8. Aug. 20 9. Aug. 27
10. Sept. 04 11. Sept. 10 12. Sept. 18 13. Sept. 25
14. Oct. 08 15. Oct. 14

1975



1. May 13 2. May 27 3. June 09 4. June 16
5. June 23 6. July 02 7. July 08 8. July 14 9. July 21
10. July 28 11. Aug. 05 12. Aug. 11 13. Aug. 18
14. Aug. 25 15. Sept. 02 16. Sept. 15 17. Oct. 02
18. Oct. 14 19. Nov. 11

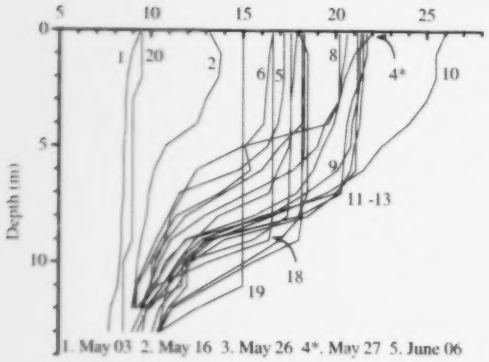
1976



1. Apr. 29 2. May 05 3. May 09 4. May 11 5. May 18
6. May 26 7. May 31 8. June 08 9. June 14 10. June 22
11. June 28 12. July 05 13. July 19 14. July 26
15. August 03 16. August 09 17. August 16 18. August 24
19. Sept. 01 20. Sept. 07 21. Sept. 20 22. Oct 06
23. Oct. 26

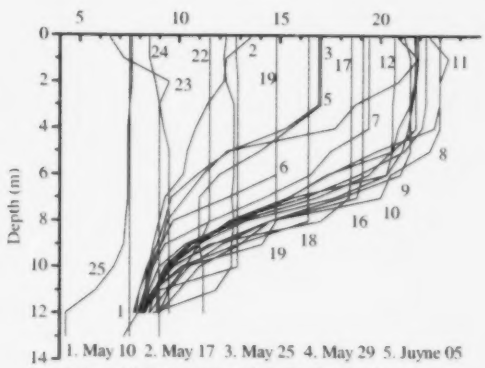
Figure 8h cont'd. Middle Lake - Temperature (°C) Profiles

1977



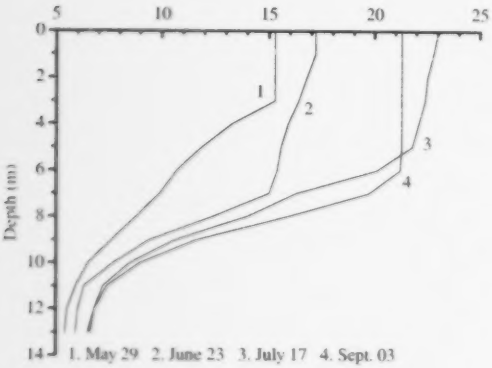
1. May 03 2. May 16 3. May 26 4*. May 27 5. June 06
6. June 13 7. June 20 8. June 27 8. July 07 10. July 13
11. July 20 12. July 27 13. Aug. 04 14. Aug. 09
15. Aug. 18 16. Aug. 23 17. Aug. 30 18. Sept. 06
19. Sept. 26 20. Nov. 17

1978



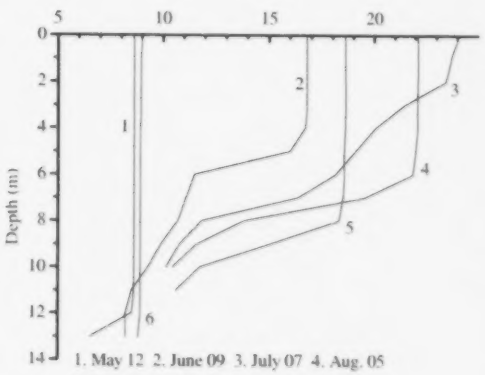
1. May 10 2. May 17 3. May 25 4. May 29 5. Juyne 05
6. June 14 7. June 26 8. July 06 9. July 10
10. July 20 11. July 24 12. Aug. 03 13. Aug. 08 14. Aug. 17
15. Aug. 21 16. Aug. 31 17. Sept. 05 18. Sept. 14
19. Sept. 18 20. Sept. 28 21. Oct. 02 22. Oct. 13 23. Oct. 16
24. Oct. 23 25. Oct. 30

1980



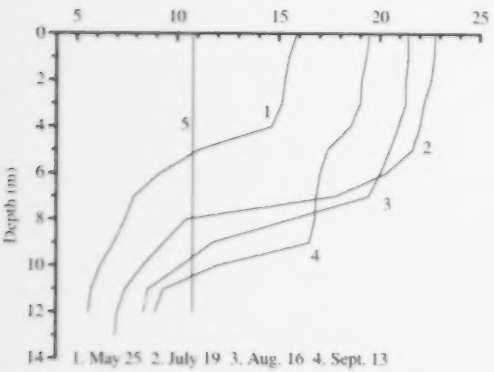
1. May 29 2. June 23 3. July 17 4. Sept. 03

1981



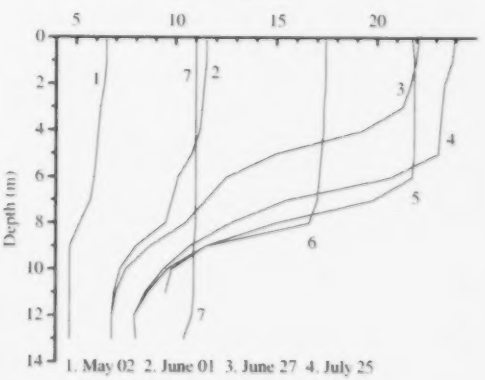
1. May 12 2. June 09 3. July 07 4. Aug. 05
5. Sept. 10 6. Oct. 20

1982



1. May 25 2. July 19 3. Aug. 16 4. Sept. 13
5. Oct. 19

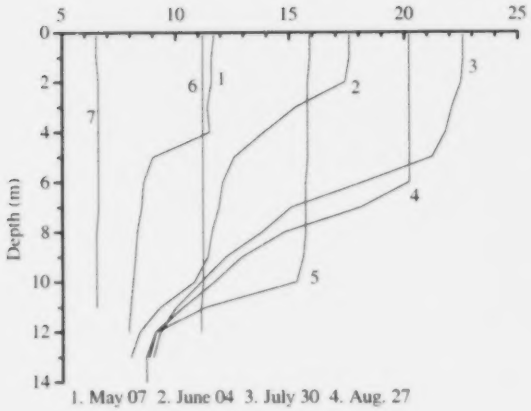
1983



1. May 02 2. June 01 3. June 27 4. July 25
5. Aug. 22 6. Sept. 19 7. Oct. 17

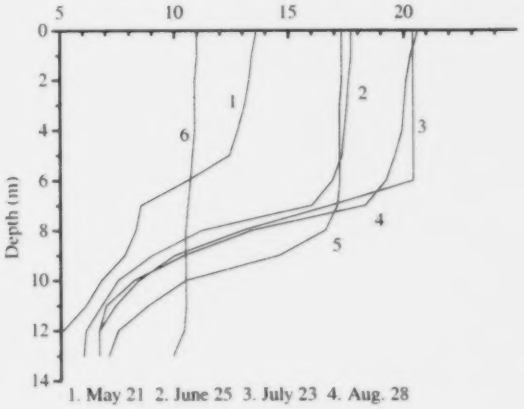
Figure 8h cont'd. Middle Lake - Temperature (°C) Profiles

1984



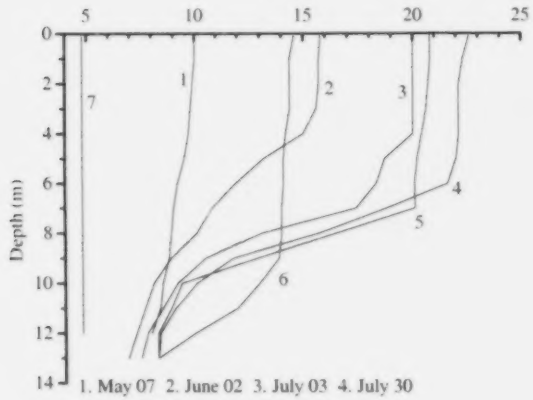
1. May 07 2. June 04 3. July 30 4. Aug. 27
5. Sept. 24 6. Oct. 22 7. Nov. 08

1985



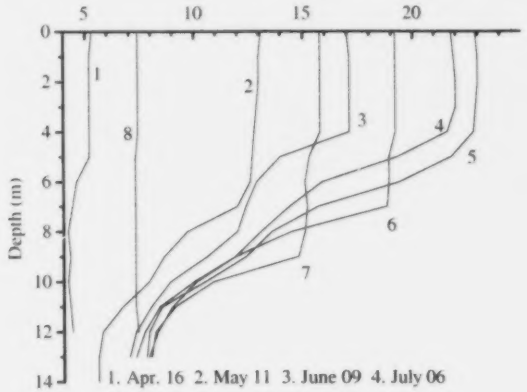
1. May 21 2. June 25 3. July 23 4. Aug. 28
5. Sept. 23 6. Oct. 21

1986



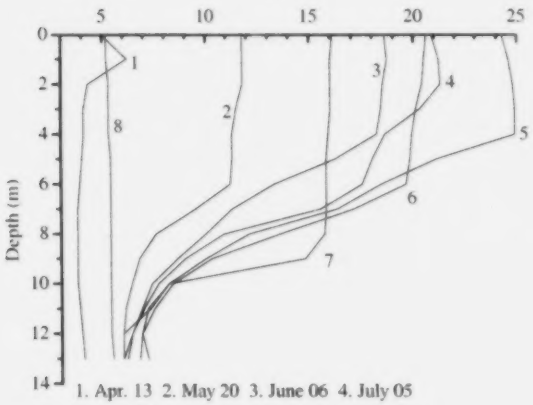
1. May 07 2. June 02 3. July 03 4. July 30
5. Aug. 25 6. Sept. 29 7. Nov. 11

1987



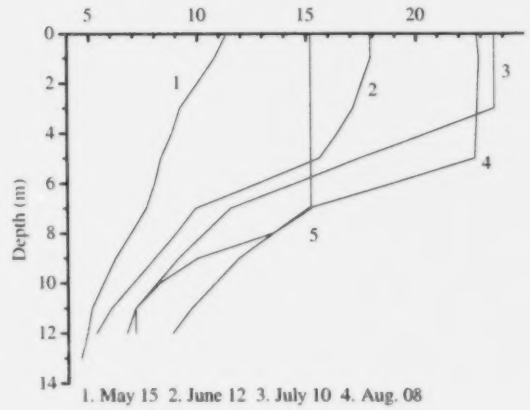
1. Apr. 16 2. May 11 3. June 09 4. July 06
5. Aug. 04 6. Aug. 31 7. Sept. 28 8. Oct. 26

1988



1. Apr. 13 2. May 20 3. June 06 4. July 05
5. Aug. 02 6. Aug. 29 7. Sept. 26 8. Nov. 02

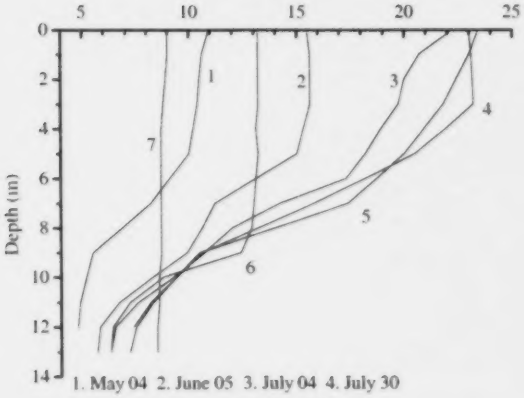
1989



1. May 15 2. June 12 3. July 10 4. Aug. 08
5. Sept. 25

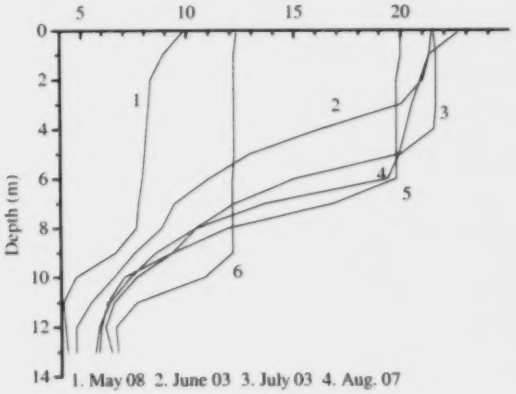
Figure 8h cont'd. Middle Lake - Temperature (°C) Profiles

1990



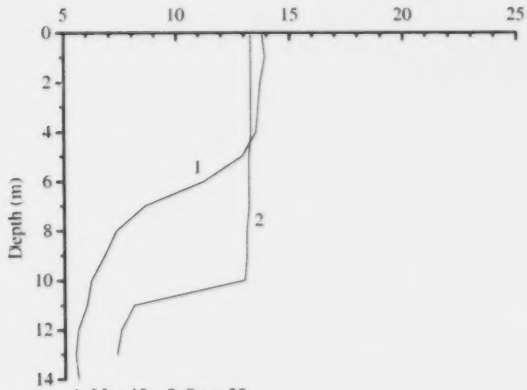
1. May 04 2. June 05 3. July 04 4. July 30
5. Aug. 27 6. Sept. 24 7. Oct. 22

1991



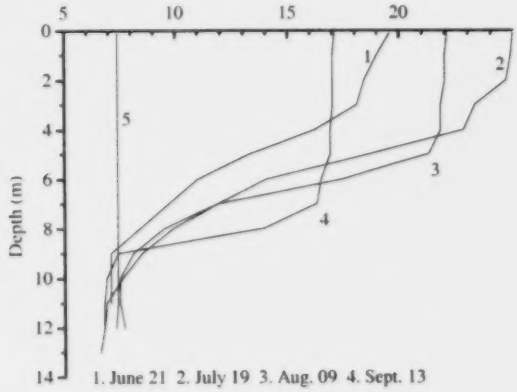
1. May 08 2. June 03 3. July 03 4. Aug. 07
5. Sept. 04 6. Oct. 02

1992



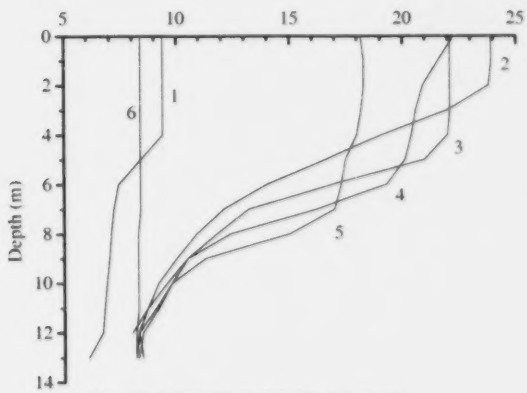
1. May 19 2. Sept. 30

1993



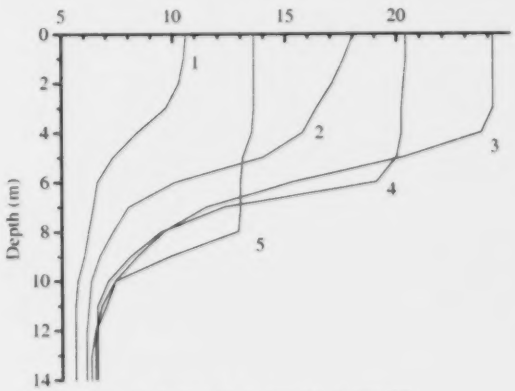
1. June 21 2. July 19 3. Aug. 09 4. Sept. 13
5. Oct. 28

1994



1. May 10 2. June 21 3. July 28 4. Aug. 22
5. Sept. 22 6. Nov. 03

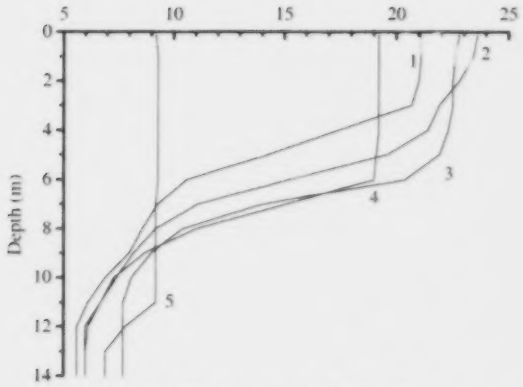
1995



1. May 11 2. June 15 3. Aug. 01 4. Aug. 30
5. Sept. 28

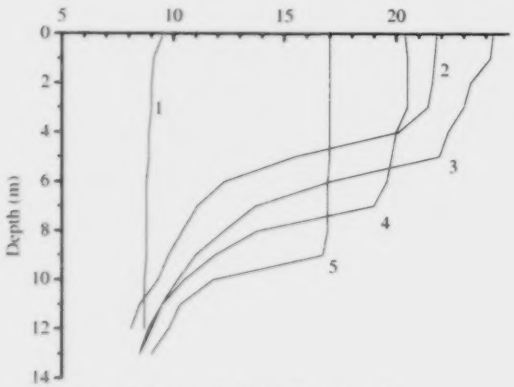
Figure 8h cont'd. Middle Lake - Temperature (°C) Profiles

1996



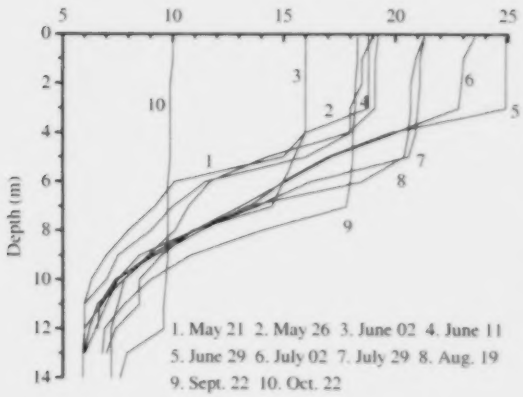
1. June 20 2. July 17 3. Aug. 20 4. Sept. 13
5. Oct. 16

1997



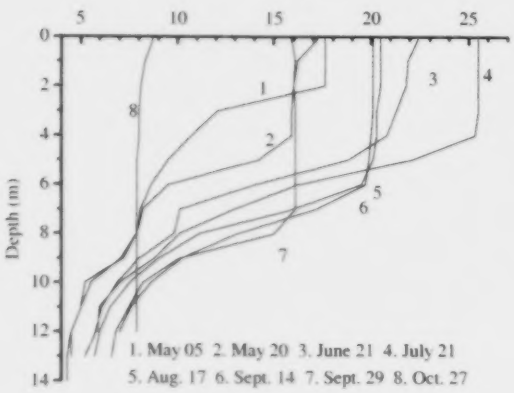
1. May 21 2. June 27 3. July 23 4. Aug. 20
5. Sept. 23

1998



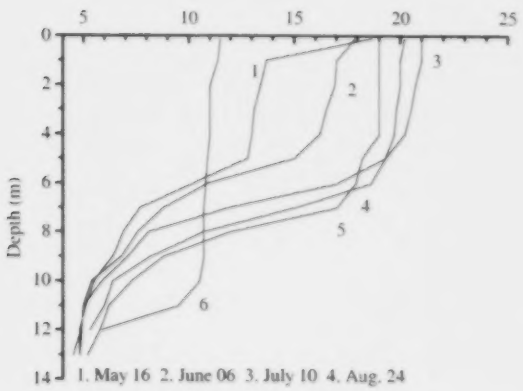
1. May 21 2. May 26 3. June 02 4. June 11
5. June 29 6. July 02 7. July 29 8. Aug. 19
9. Sept. 22 10. Oct. 22

1999



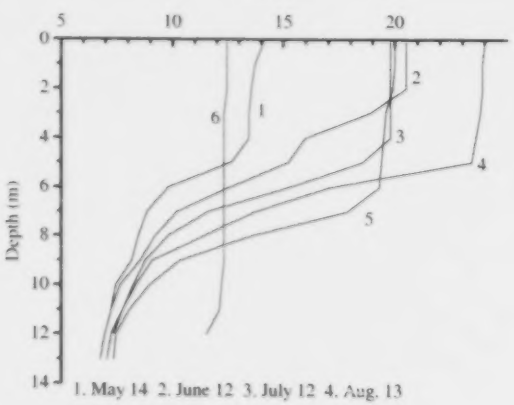
1. May 05 2. May 20 3. June 21 4. July 21
5. Aug. 17 6. Sept. 14 7. Sept. 29 8. Oct. 27

2000



1. May 16 2. June 06 3. July 10 4. Aug. 24
5. Sept. 11 6. Oct. 11

2001



1. May 14 2. June 12 3. July 12 4. Aug. 13
5. Sept. 11 6. Oct. 15

Figure 8i. Middle Lake epilimnetic depth on the dates of maximum heat content

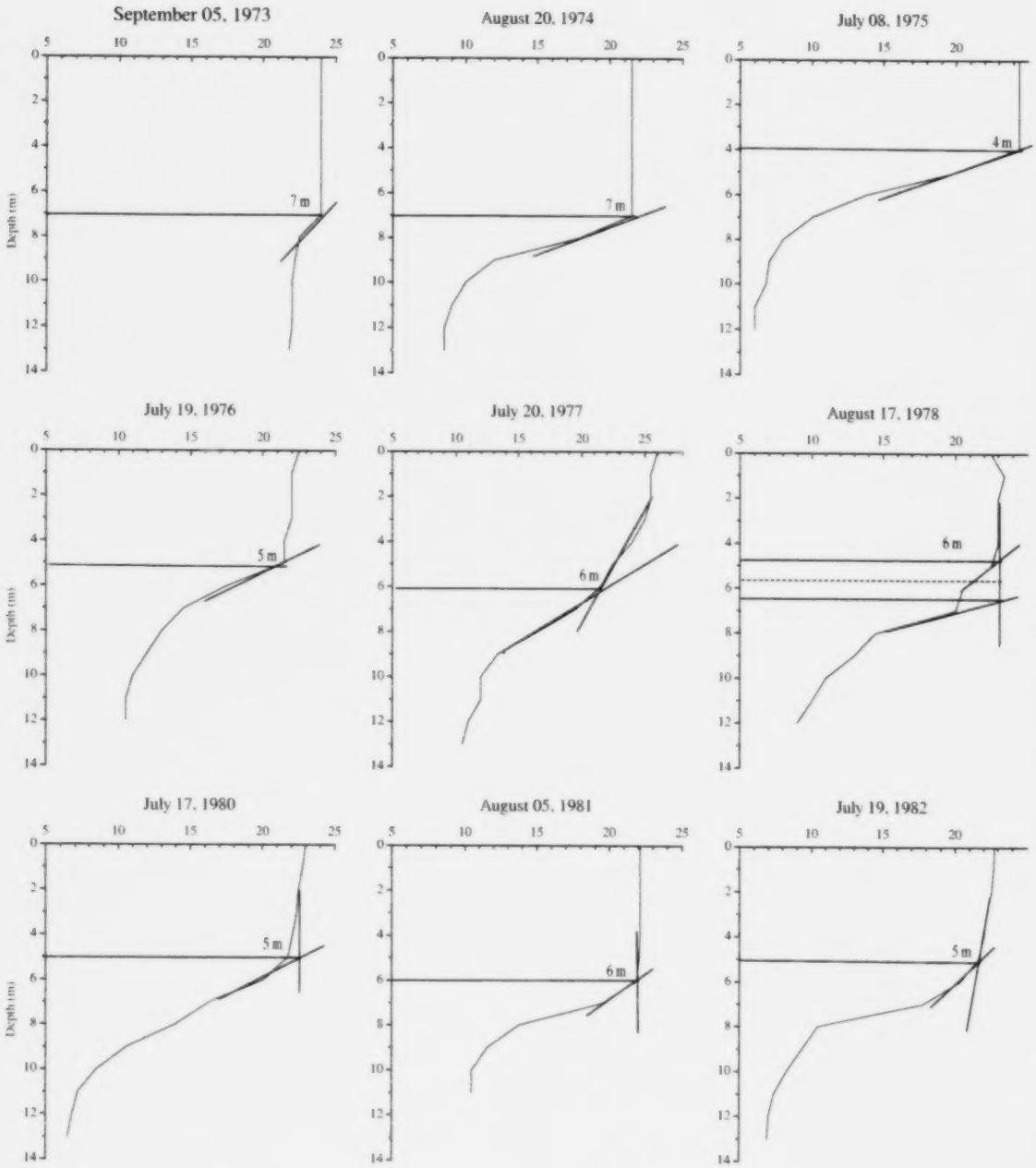


Figure 8i cont'd. Middle Lake epilimnetic depth on the dates of maximum heat content

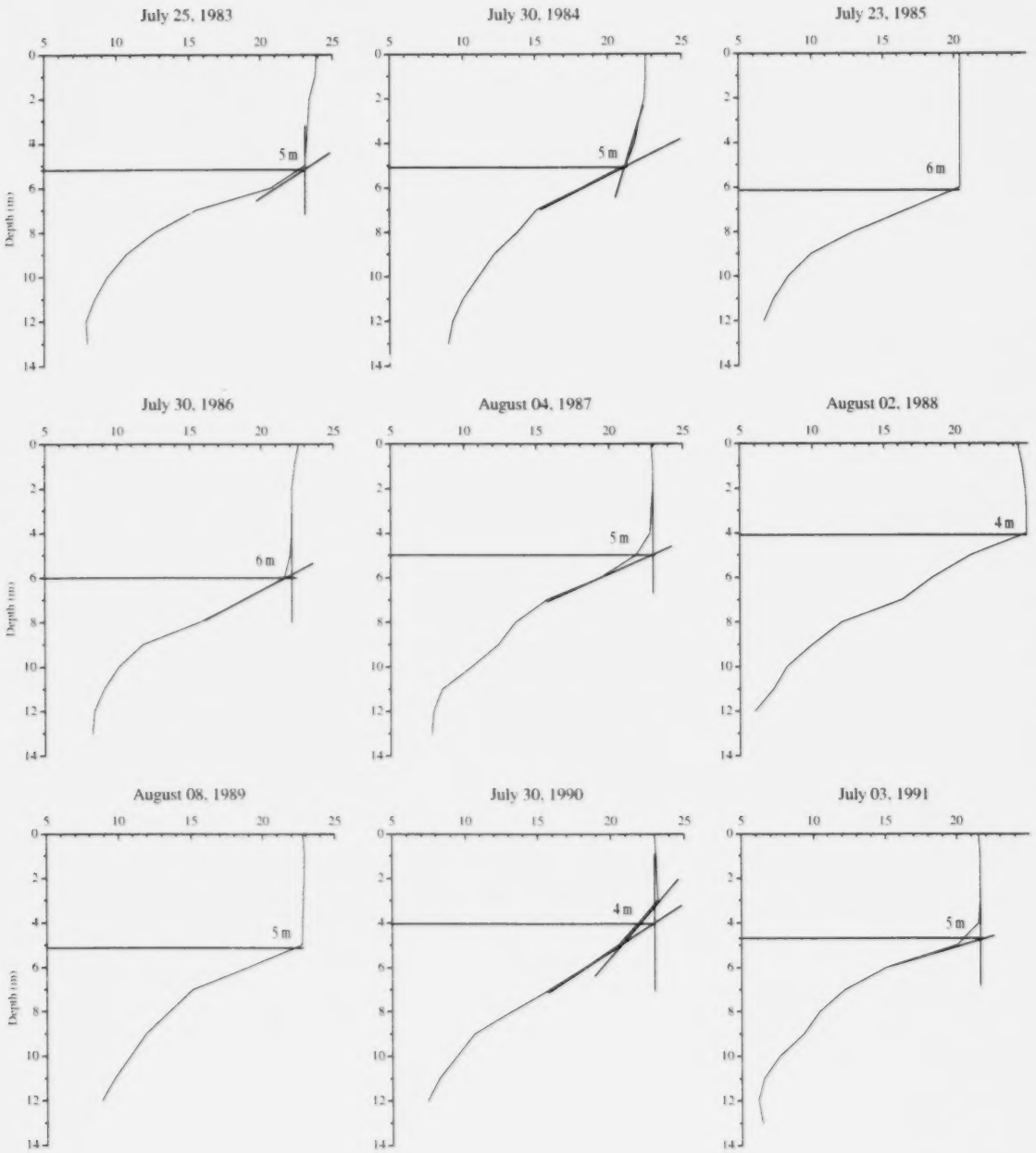


Figure 8i cont'd. Middle Lake epilimnetic depth on the dates of maximum heat content

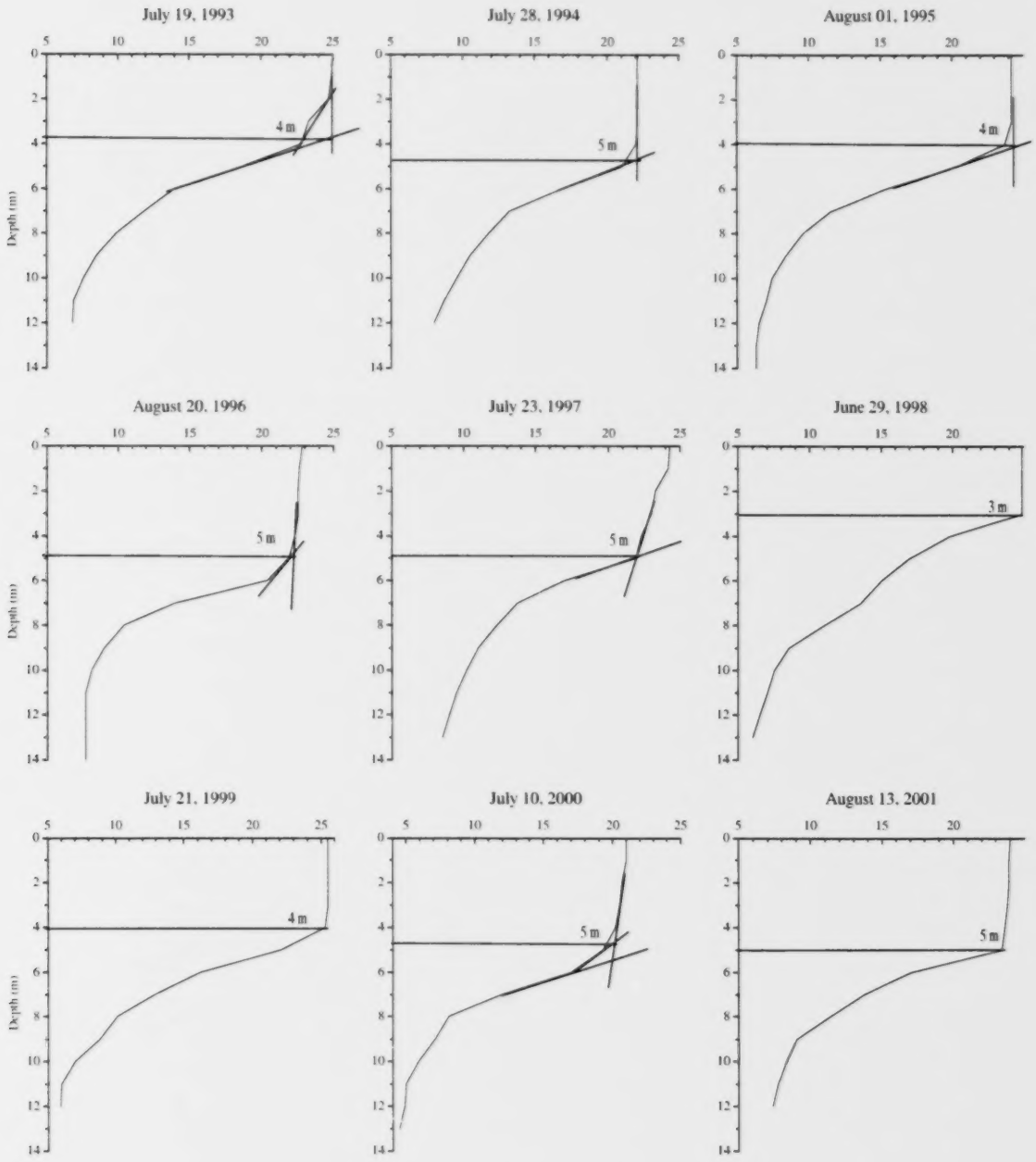


Figure 8j. Middle Lake - Recent dissolved oxygen (mg • L^{-1} of O^{2})

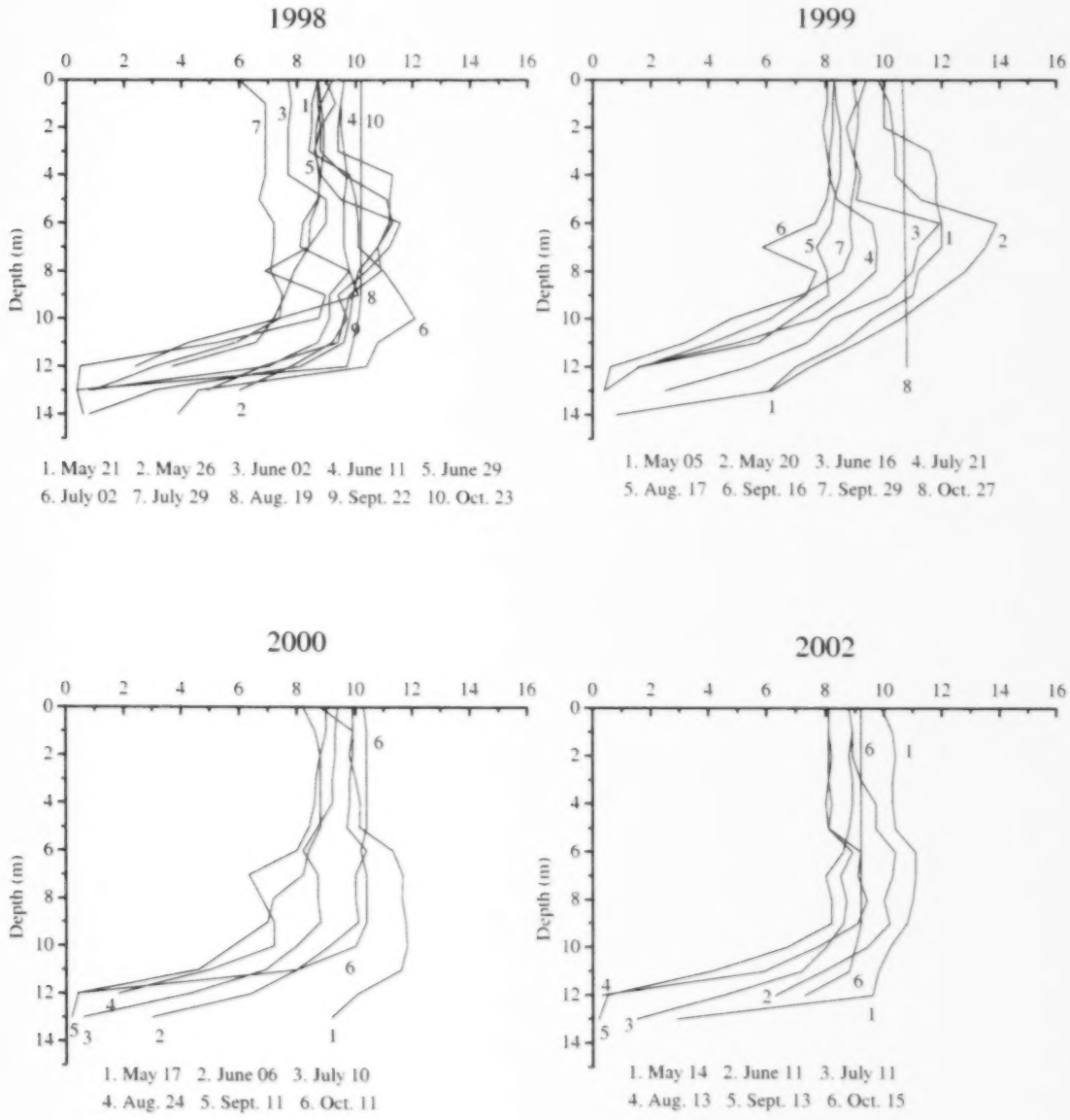

1998
1999
2000
2002
Depth (m)
1. May 21 2. May 26 3. June 02 4. June 11 5. June 29
6. July 02 7. July 29 8. Aug. 19 9. Sept. 22 10. Oct. 23
1. May 05 2. May 20 3. June 16 4. July 21
5. Aug. 17 6. Sept. 16 7. Sept. 29 8. Oct. 27
1. May 17 2. June 06 3. July 10
4. Aug. 24 5. Sept. 11 6. Oct. 11
1. May 14 2. June 11 3. July 11
4. Aug. 13 5. Sept. 13 6. Oct. 15

Figure 9a : Hannah Lake - Base Cations and pH

(* post - liming value in 1975)

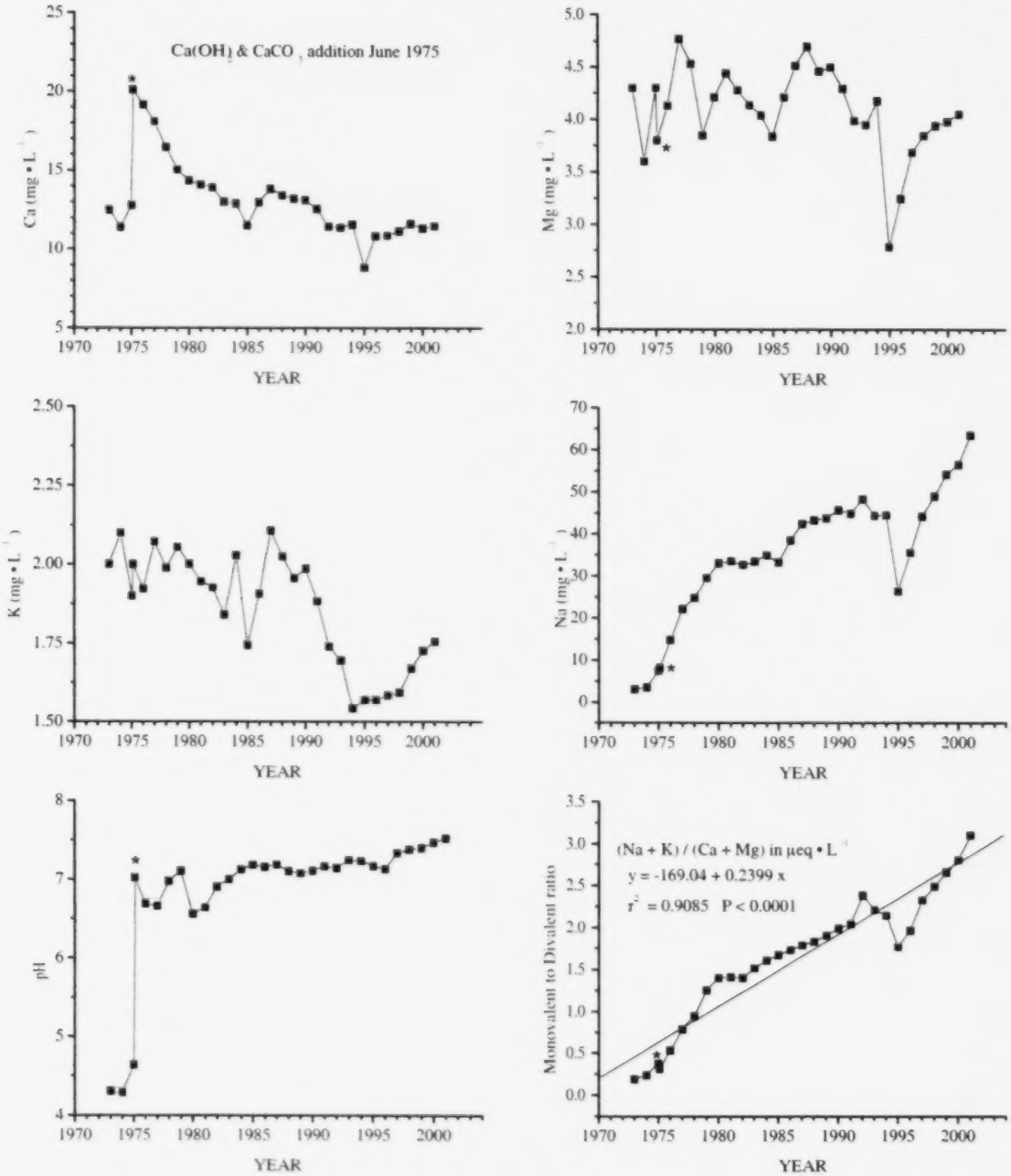

Ca(OH)2 & CaCO3 addition June 1975
Ca (mg • L-1)
Mg (mg • L-1)
K (mg • L-1)
Na (mg • L-1)
pH
Monovalent to Divalent ratio
(Na + K) / (Ca + Mg) in µeq • L-1
y = -169.04 + 0.2399 x
r2 = 0.9085 P < 0.0001
YEAR

Figure 9b : Hannah Lake - Anions & related variables:

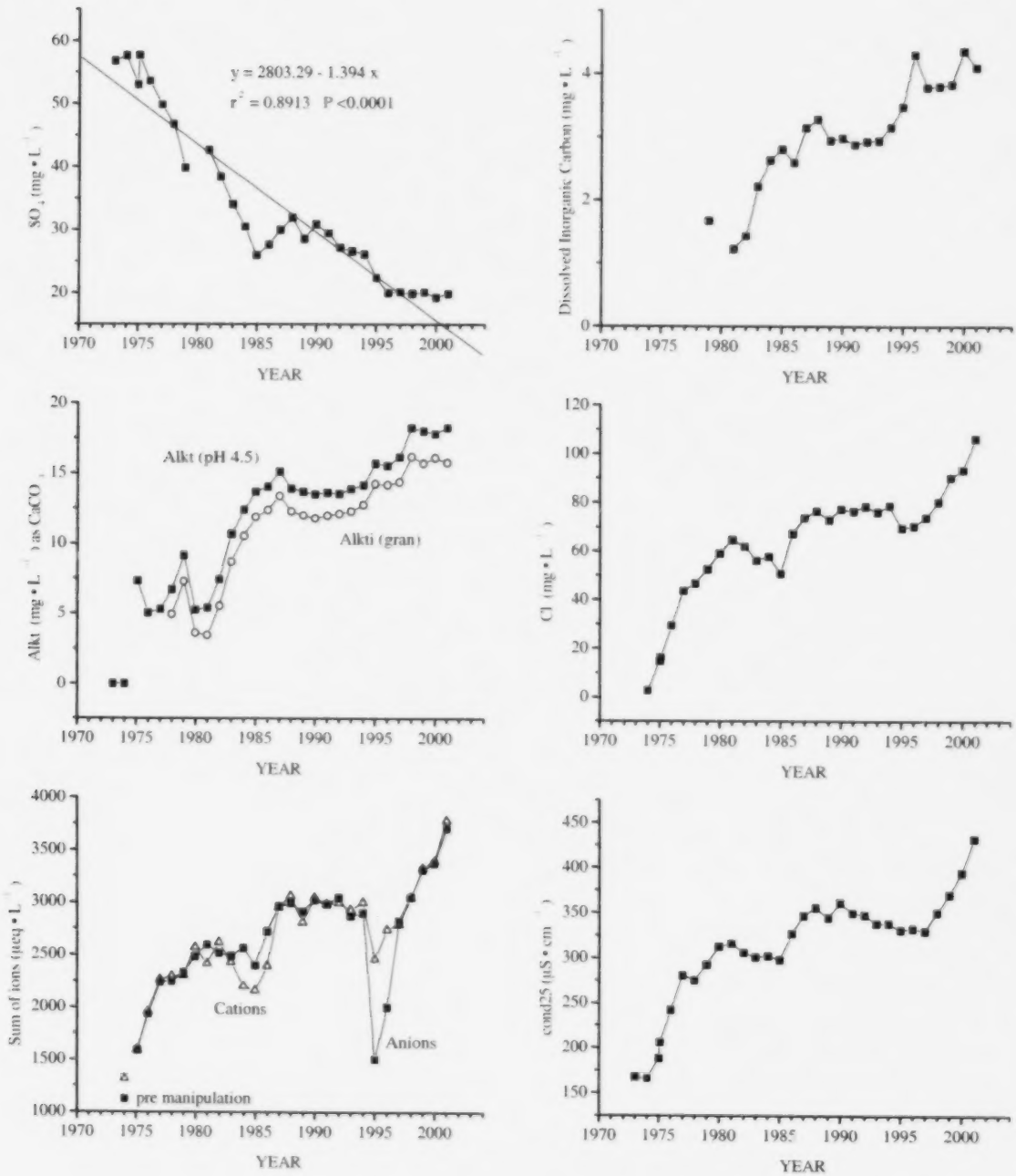


Figure 9c : Hannah Lake - metals

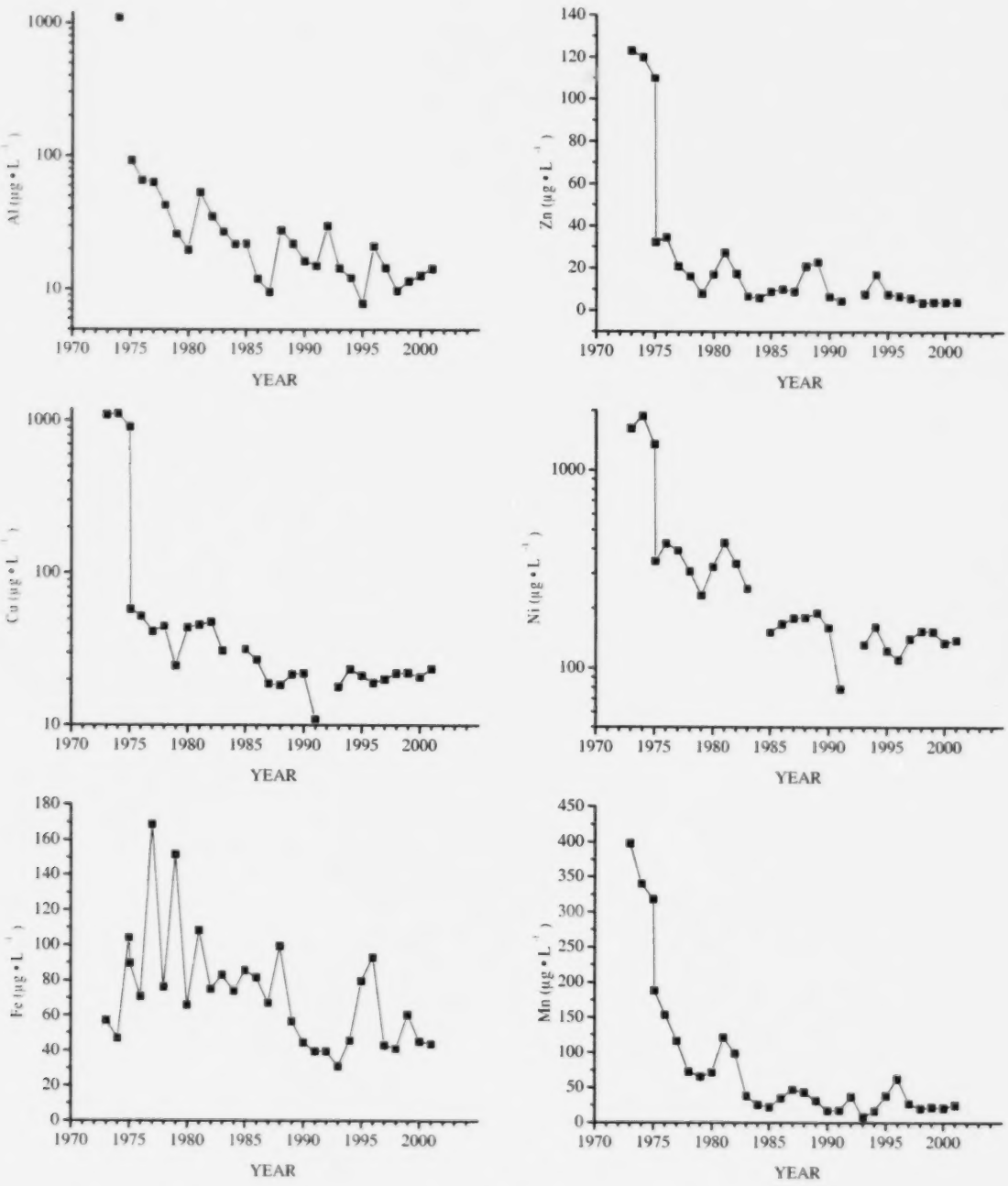
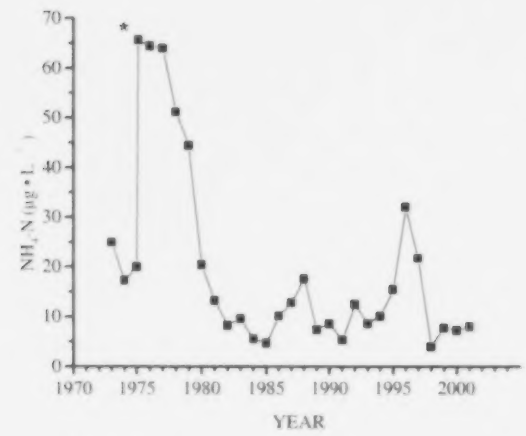
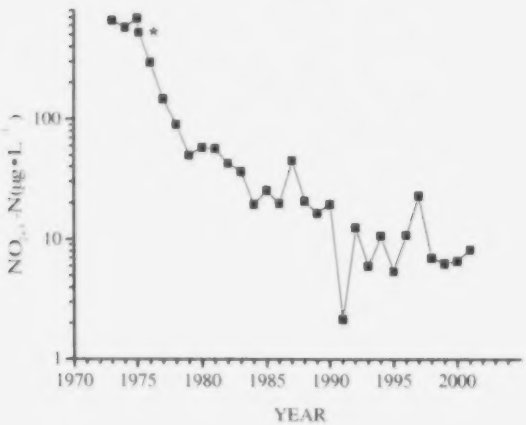
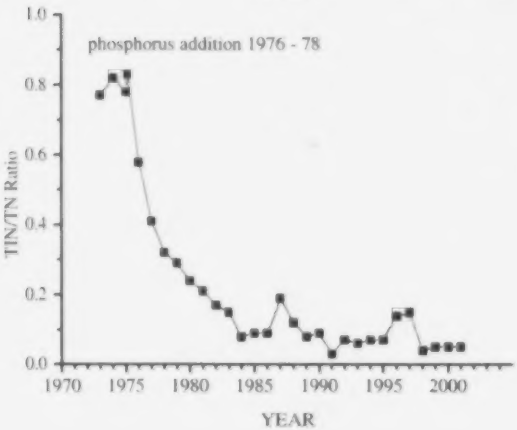


Figure 9d : Hannah Lake - Nitrogen species and TIN / TN ratio

(* post - liming)







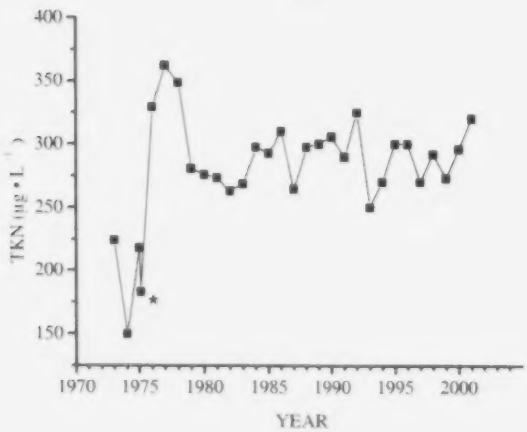


Figure 9e : Hannah Lake - trophic indicators :
(* year TP analysis moved away from sewage plant in Sudbury)

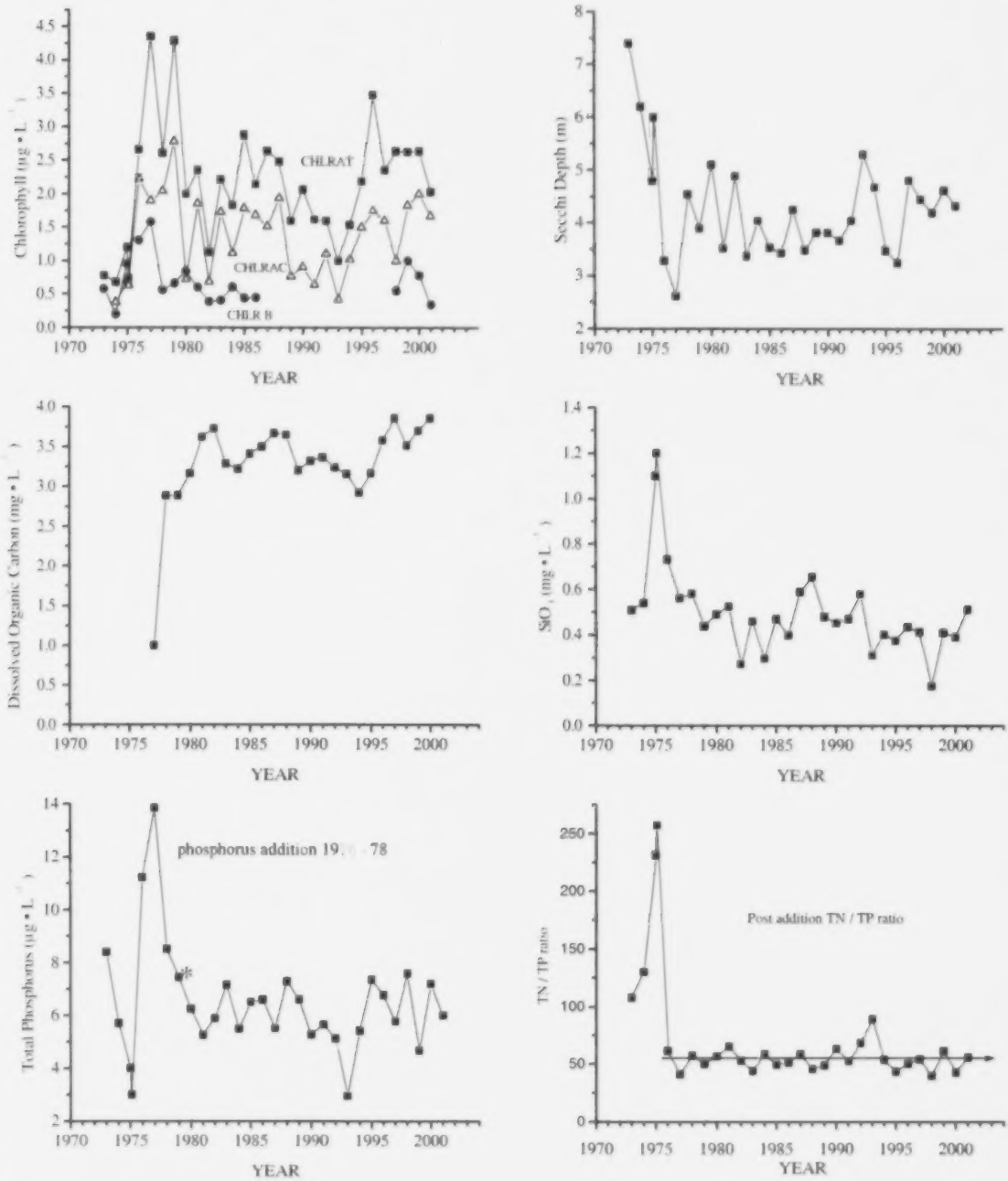
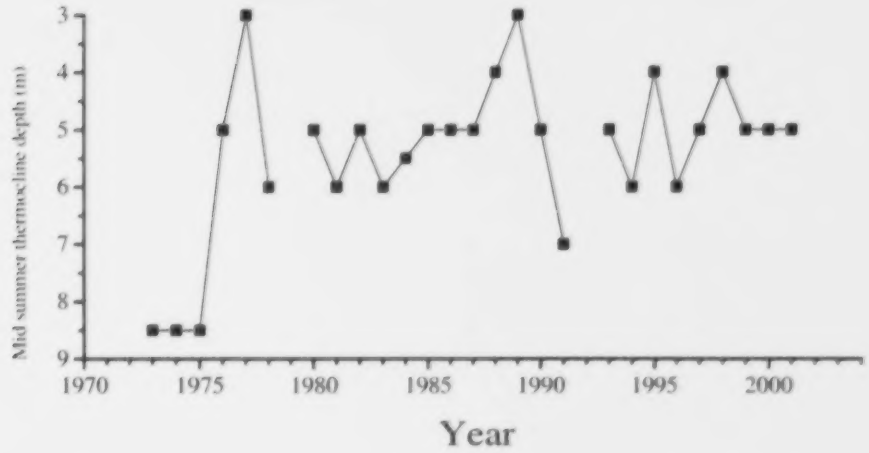
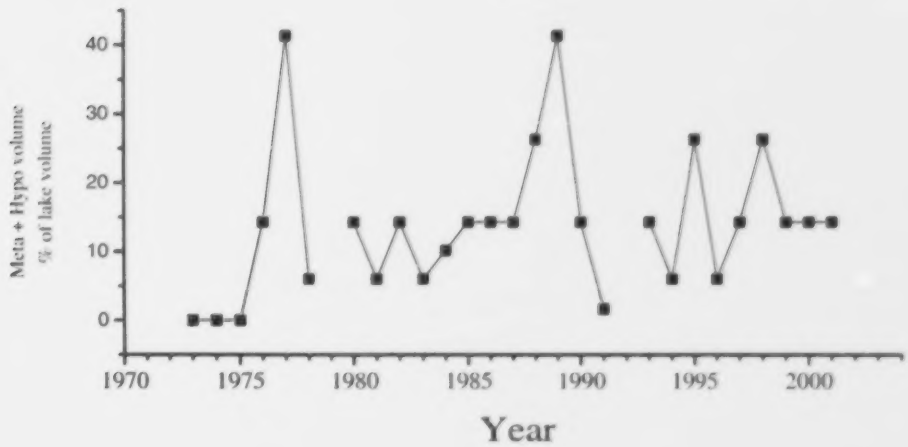


Figure 9f. Hannah Lake changes in thermocline depth and increase in meta + hypolimnetic % total volume, and concurrent changes in mid summer surface and deep water temperatures.





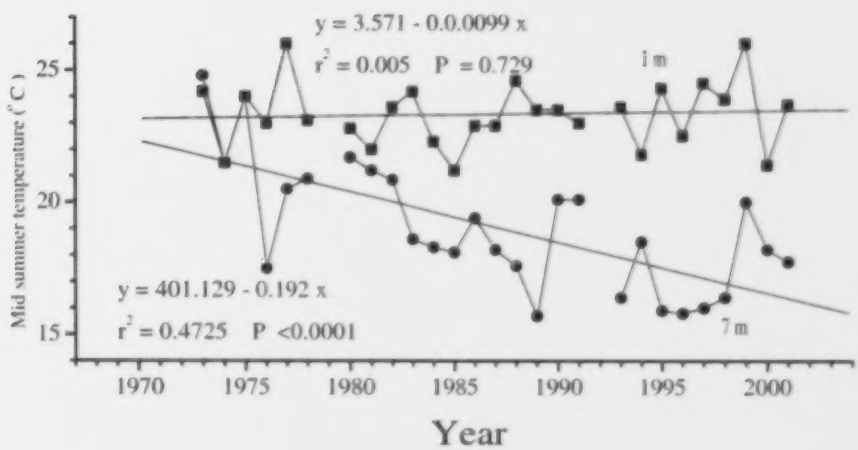


Figure 9g : Hannah Lake changes in maximum heat content (cal • m^2),
maximum summer heat income ($^{\circ}C > 4^{\circ}C$),
and volume-weight average temperature ($^{\circ}C$)

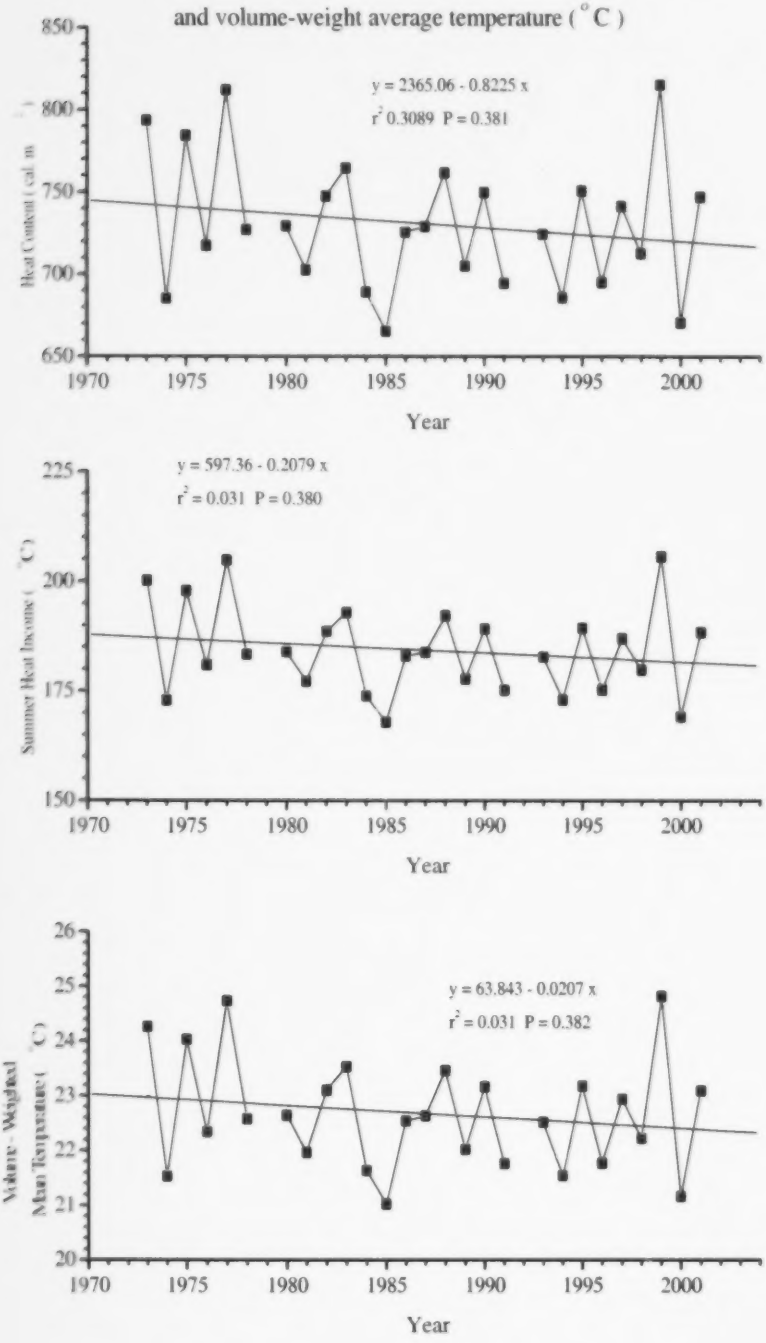
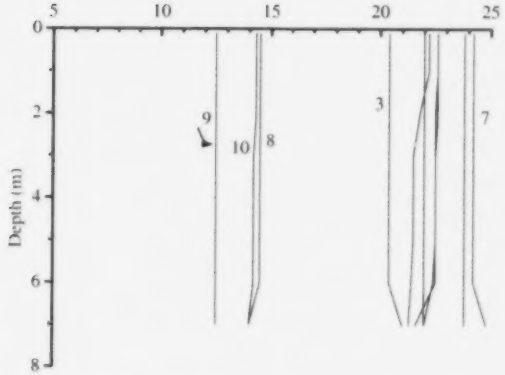


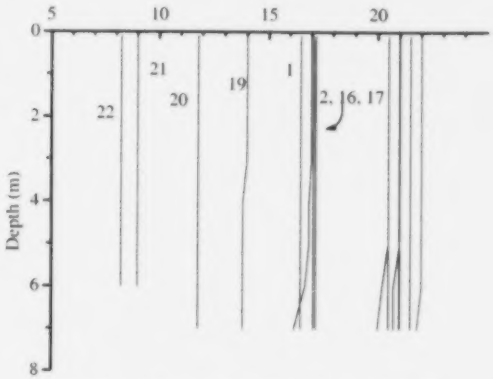
Figure 9h. Hannah Lake - Temperature (°C) Profiles

1973



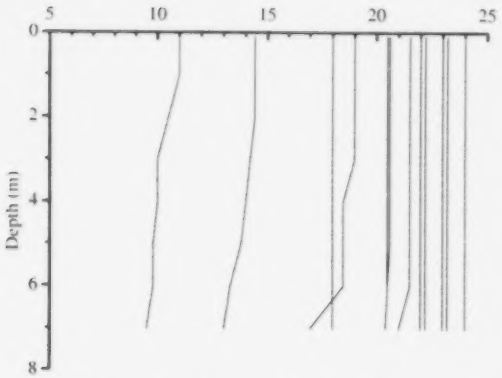
1. June 26 2. July 17 3. July31 4. Aug. 08 5. Aug. 13
6. Aug. 20 7. Sept. 05 8. Sept. 18 9. Sept. 24 10. Oct. 01

1974



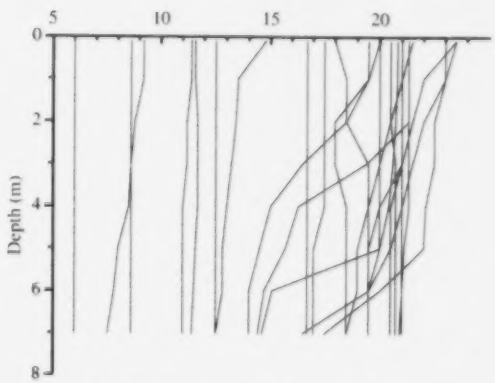
1. June 12 2. June 18 3. July 10 4. July 17 5. July 23
6. July 30 7. Aug. 06 8. Aug. 15 9. Aug. 20 16. Aug. 27
17. Sept. 04 18. Sept. 10 19. Sept. 18 20. Sept.25
21. Oct. 02 22. Oct. 08

1975



1.May 13 2. May 19 3. June 02 4. June 09 5. June 16
6. June 23 7. July 02 8. July 08 9. July 14 10. July 21
11. July 28 12. Aug. 05 13. Aug 11 14. Aug. 18 15. Aug. 25

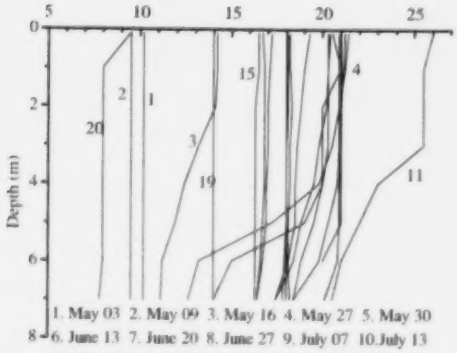
1976



1. Apr. 29 2. May 05 3. May 11 4. May 18 5. May 26
6. May 31 7. June 08 8. June 14 9. June 22 10. June 28
11. July 05 12. July 13 13. July 19 14. July 26 15. Aug. 03
16. Aug. 10 17. Aug. 16 18. Aug. 24 19. Sept. 01 20. Sept. 07
21. Sept. 20 22. Oct. 06 23. Oct. 26 24.

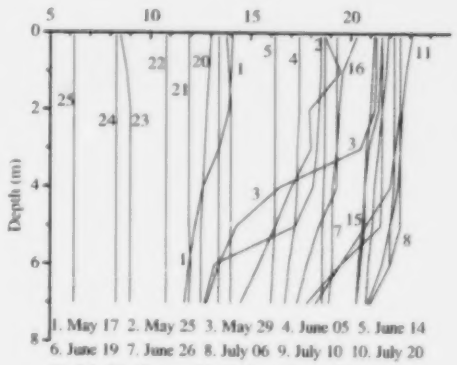
Figure 9h cont'd. Hannah Lake - Temperature (°C) Profiles

1977



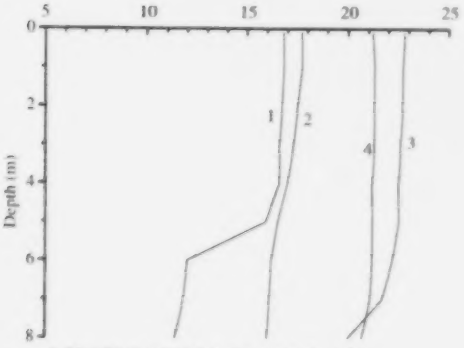
1. May 03 2. May 09 3. May 16 4. May 27 5. May 30
6. June 13 7. June 20 8. June 27 9. July 07 10.July 13
11. July 20 12. July 27 13. Aug. 09 14. Aug. 18
15. Aug. 23 16. Aug. 30 17. Sept. 06 18. Sept. 14
19. Sept. 26 20. Oct. 17

1978



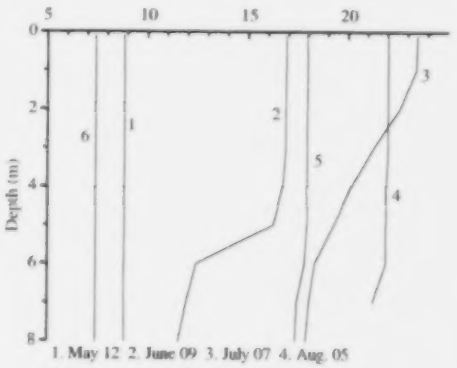
1. May 17 2. May 25 3. May 29 4. June 05 5. June 14
6. June 19 7. June 26 8. July 06 9. July 10 10. July 20
11. July 24 12. Aug. 03 13. Aug. 08 14. Aug. 17
15. Aug. 21 16. Aug. 31 17. Sept. 05 18. Sept. 14
19. Sept. 18 20. Sept. 28 21. Oct. 02 22. Oct. 13
23. Oct. 16 24. Oct. 23 25. Oct. 30

1980



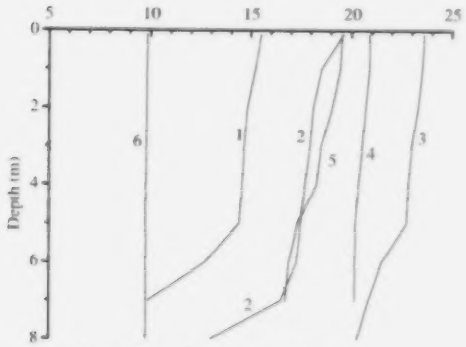
1. May 26 2. June 23 3. July 17 4. Sept. 03

1981



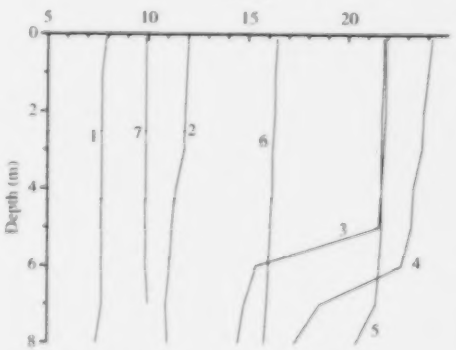
1. May 12 2. June 09 3. July 07 4. Aug. 05
5. Sept. 10 6. Oct. 20

1982



1. May 26 2. June 21 3. July 19 4. Aug. 16
5. Sept. 13 6. Oct. 19

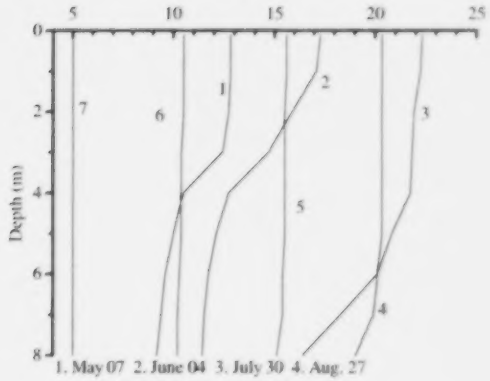
1983



1. May 03 2. June 01 3. June 27 4. July 25
5. Aug. 22 6. Sept. 19 7. Oct. 17

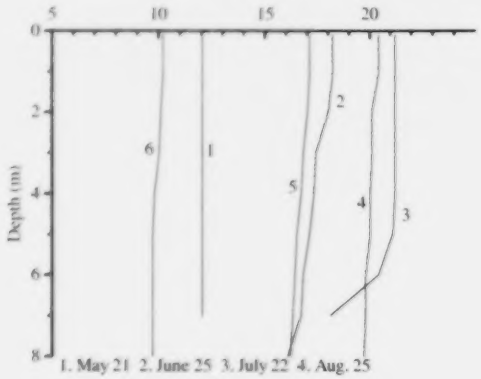
Figure 9h cont'd Hannah Lake - Temperature (°C) Profiles

1984



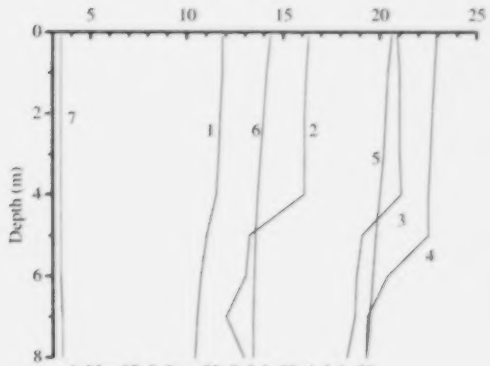
1. May 07 2. June 04 3. July 30 4. Aug. 27
5. Sept. 24 6. Oct. 22 7. Nov. 08

1985



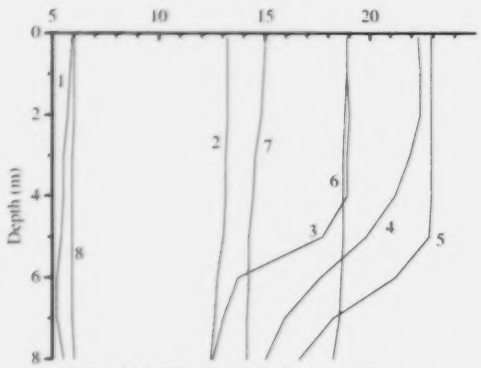
1. May 21 2. June 25 3. July 22 4. Aug. 25
5. Sept. 23 6. Oct. 21

1986



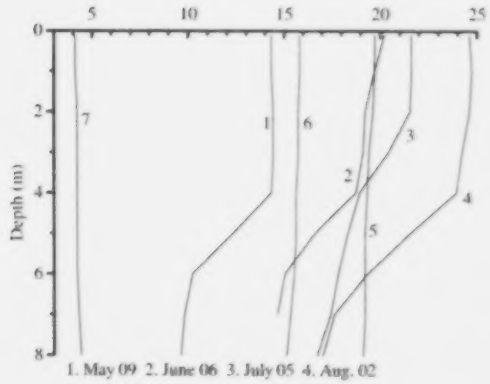
1. May 07 2. June 02 3. July 02 4. July 30
5. Aug. 25 6. Sept. 29 7. Nov. 11

1987



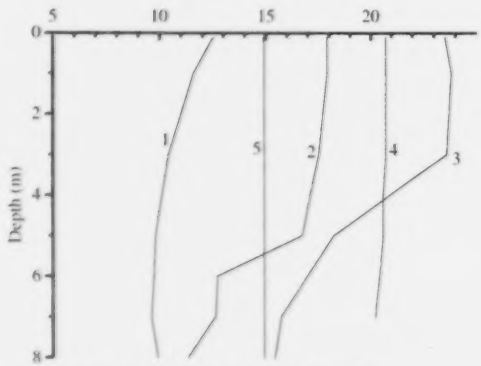
1. Apr. 16 2. May 11 3. June 08 4. July 06
5. Aug. 04 6. Aug. 31 7. Sept. 28 8. Oct. 26

1988



1. May 09 2. June 06 3. July 05 4. Aug. 02
5. Aug. 29 6. Sept. 26 7. Nov. 02

1989



1. May 15 2. June 12 3. July 10 4. Aug. 08
5. Sept. 25

Figure 9h cont'd. Hannah Lake - Temperature (°C) Profiles

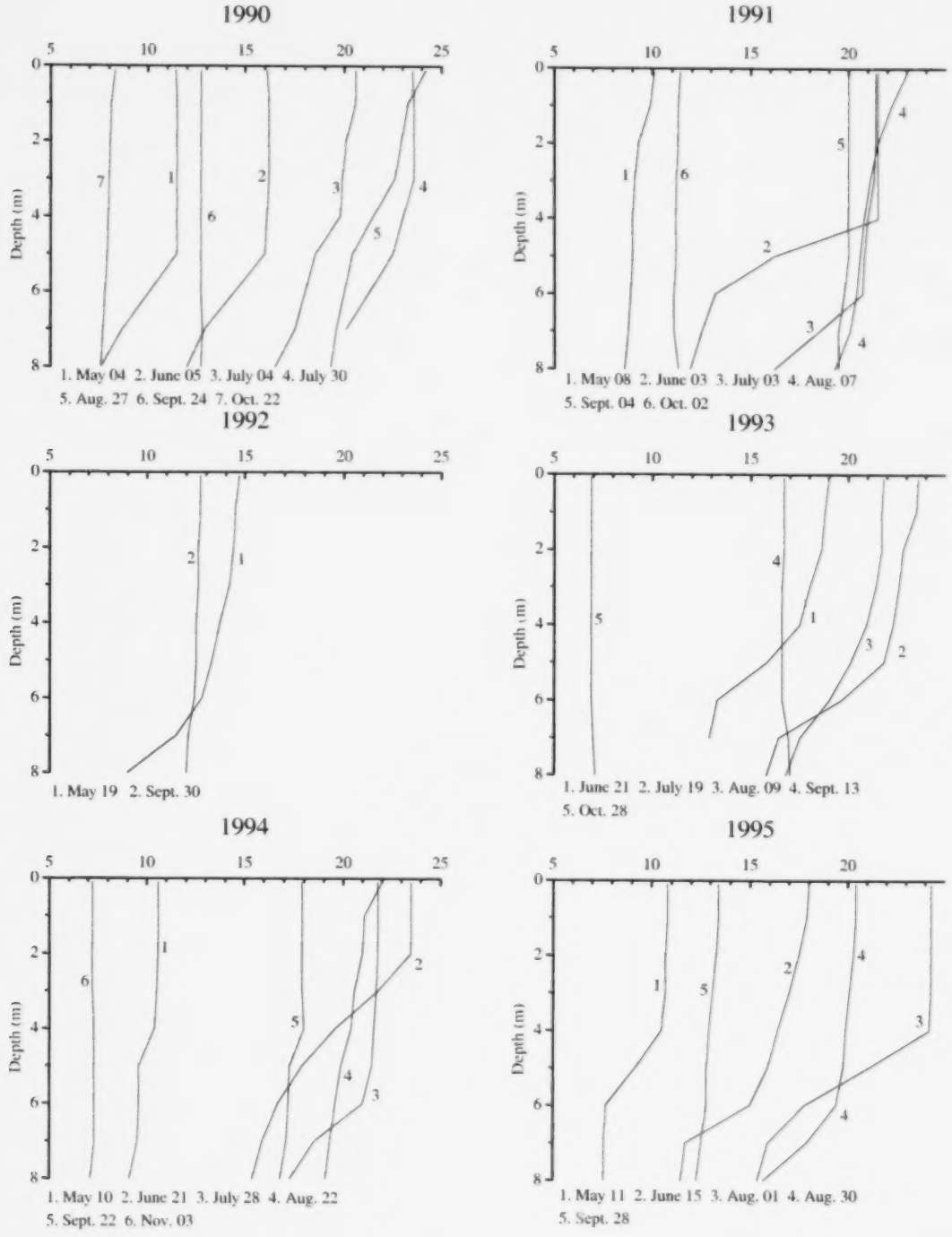


Figure 9h cont'd. Hannah Lake - Temperature (°C) Profiles

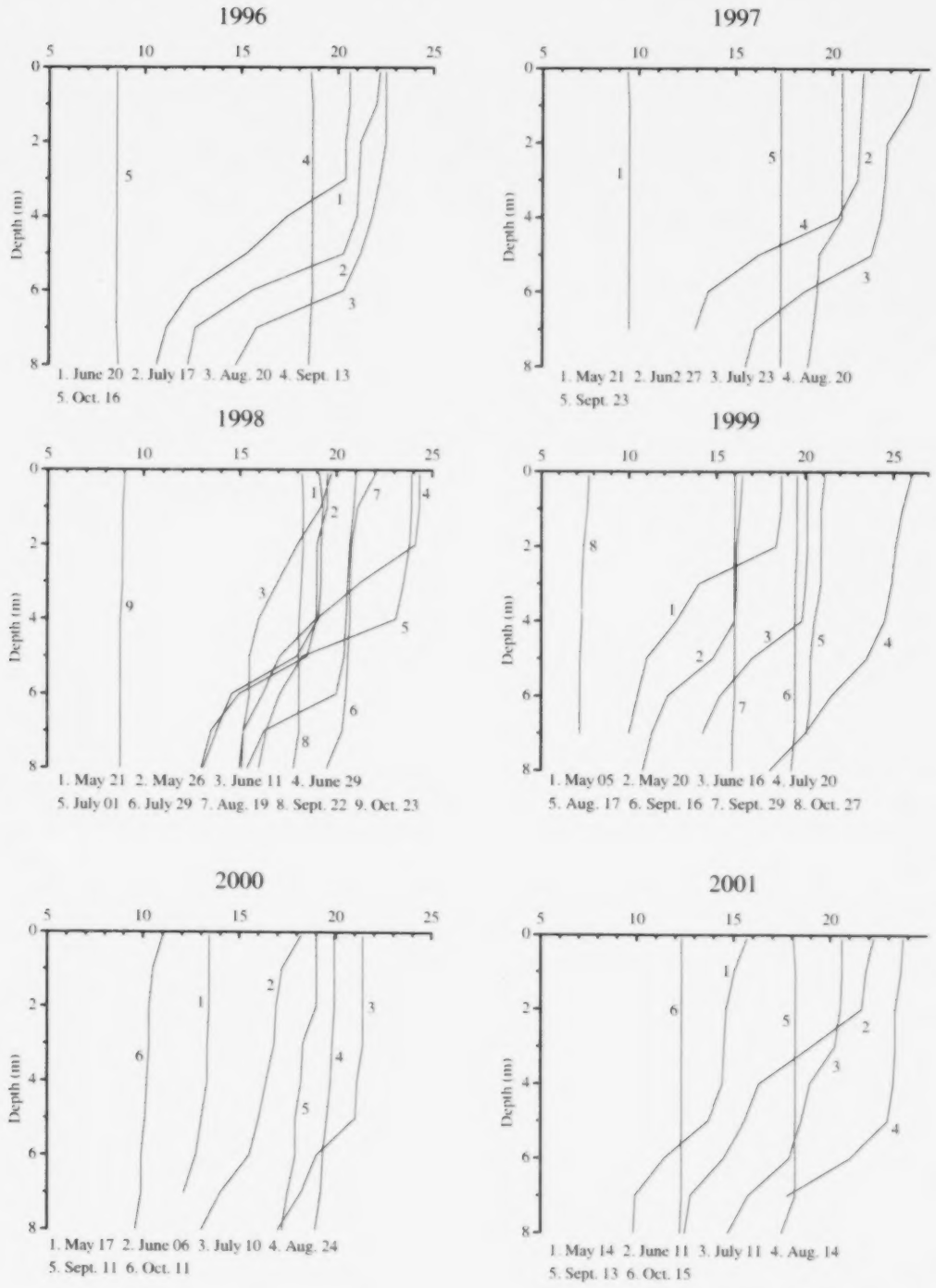

1996
1. June 20 2. July 17 3. Aug. 20 4. Sept. 13
5. Oct. 16
1997
1. May 21 2. Jun2 27 3. July 23 4. Aug. 20
5. Sept. 23
1998
1. May 21 2. May 26 3. June 11 4. June 29
5. July 01 6. July 29 7. Aug. 19 8. Sept. 22 9. Oct. 23
1999
1. May 05 2. May 20 3. June 16 4. July 20
5. Aug. 17 6. Sept. 16 7. Sept. 29 8. Oct. 27
2000
1. May 17 2. June 06 3. July 10 4. Aug. 24
5. Sept. 11 6. Oct. 11
2001
1. May 14 2. June 11 3. July 11 4. Aug. 14
5. Sept. 13 6. Oct. 15
Depth (m)

Figure 9i. Hannah Lake epilimnetic depth on the dates of maximum heat content

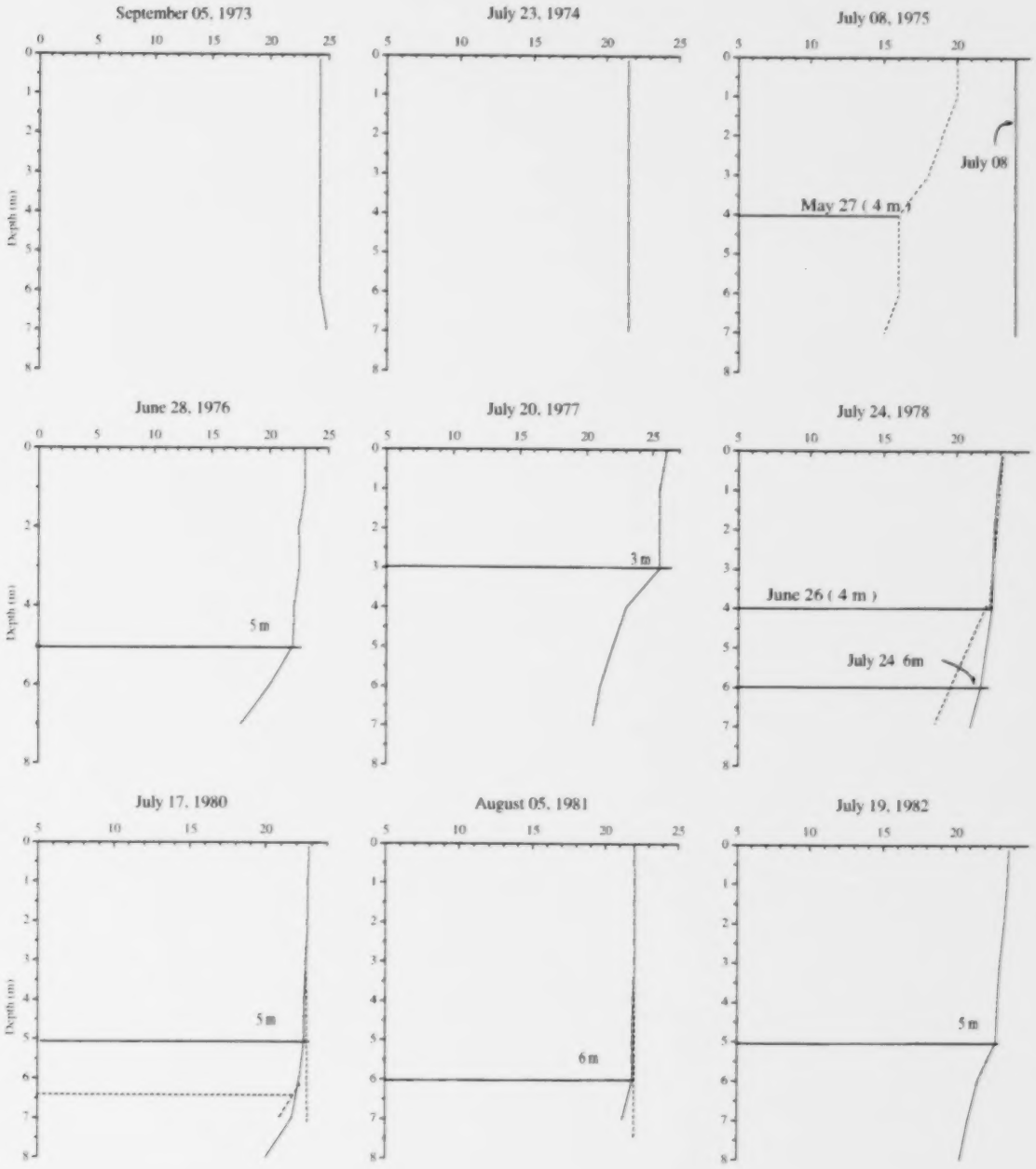


Figure 9i cont'd. Hannah Lake epilimnetic depth on the dates of maximum heat content

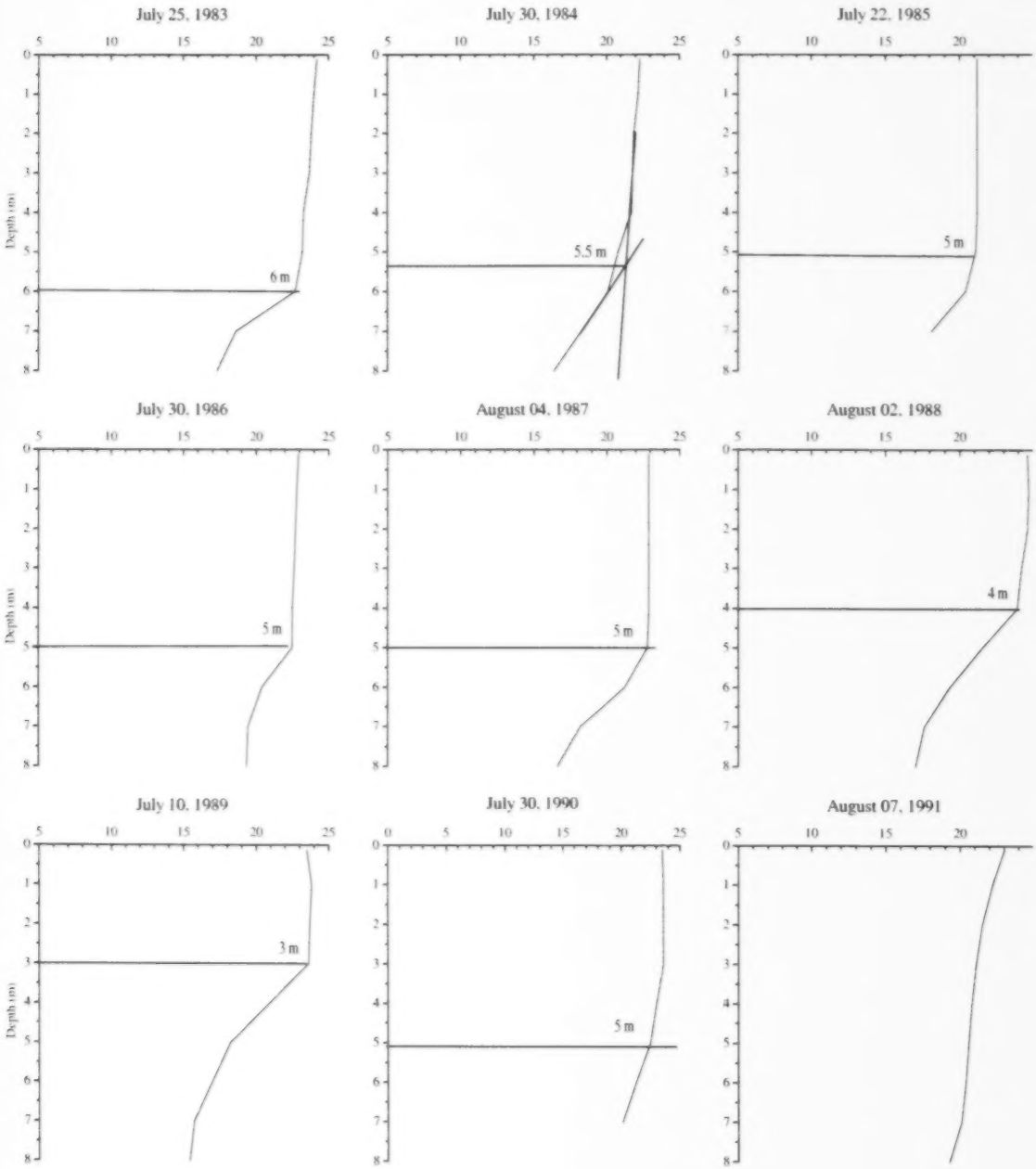


Figure 9i cont'd. Hannah Lake epilimnetic depth on the dates of maximum heat content

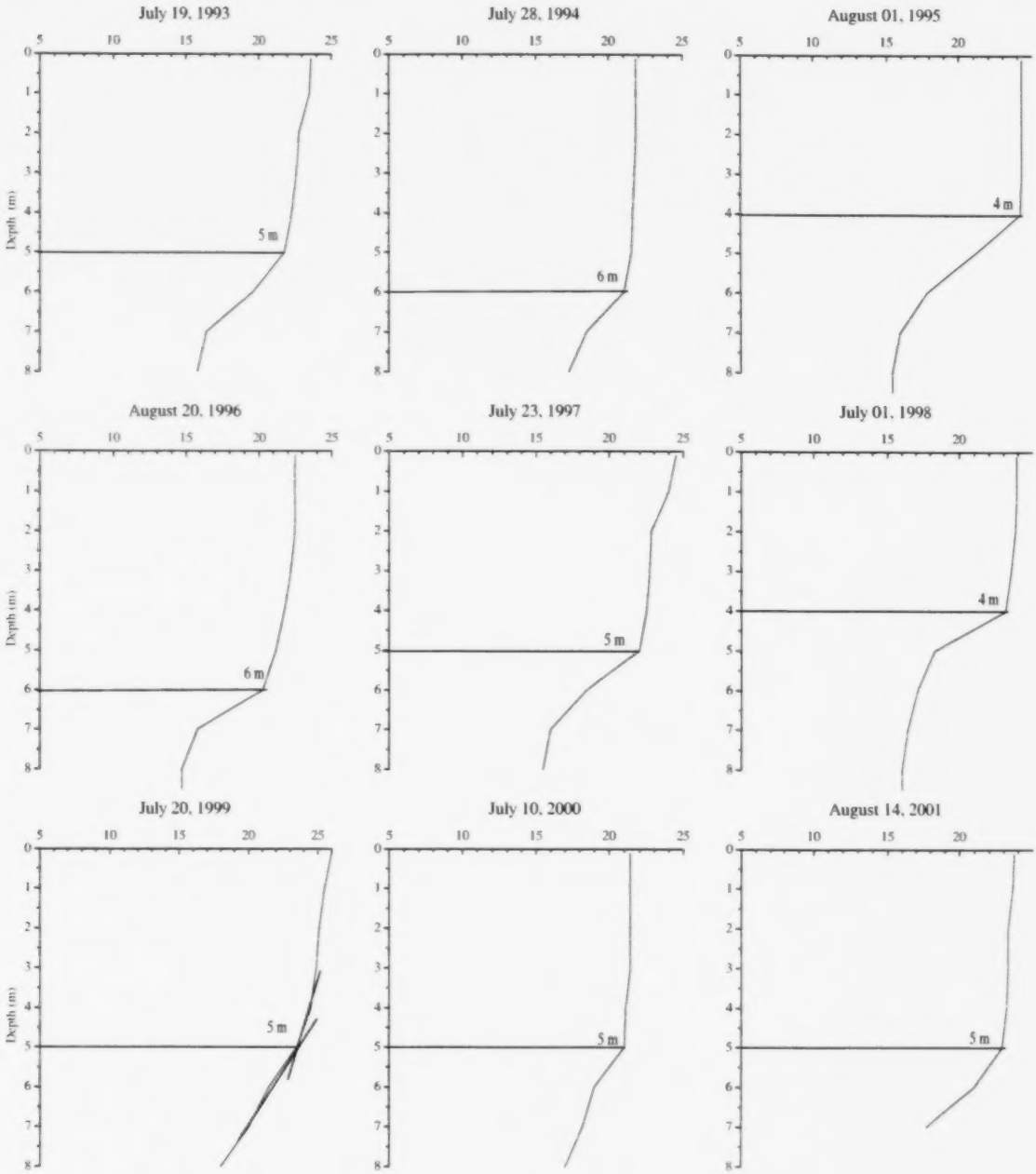


Figure 9j. Hannah Lake - Recent dissolved oxygen profiles ($mg \cdot L^{-1}$ of O_2)

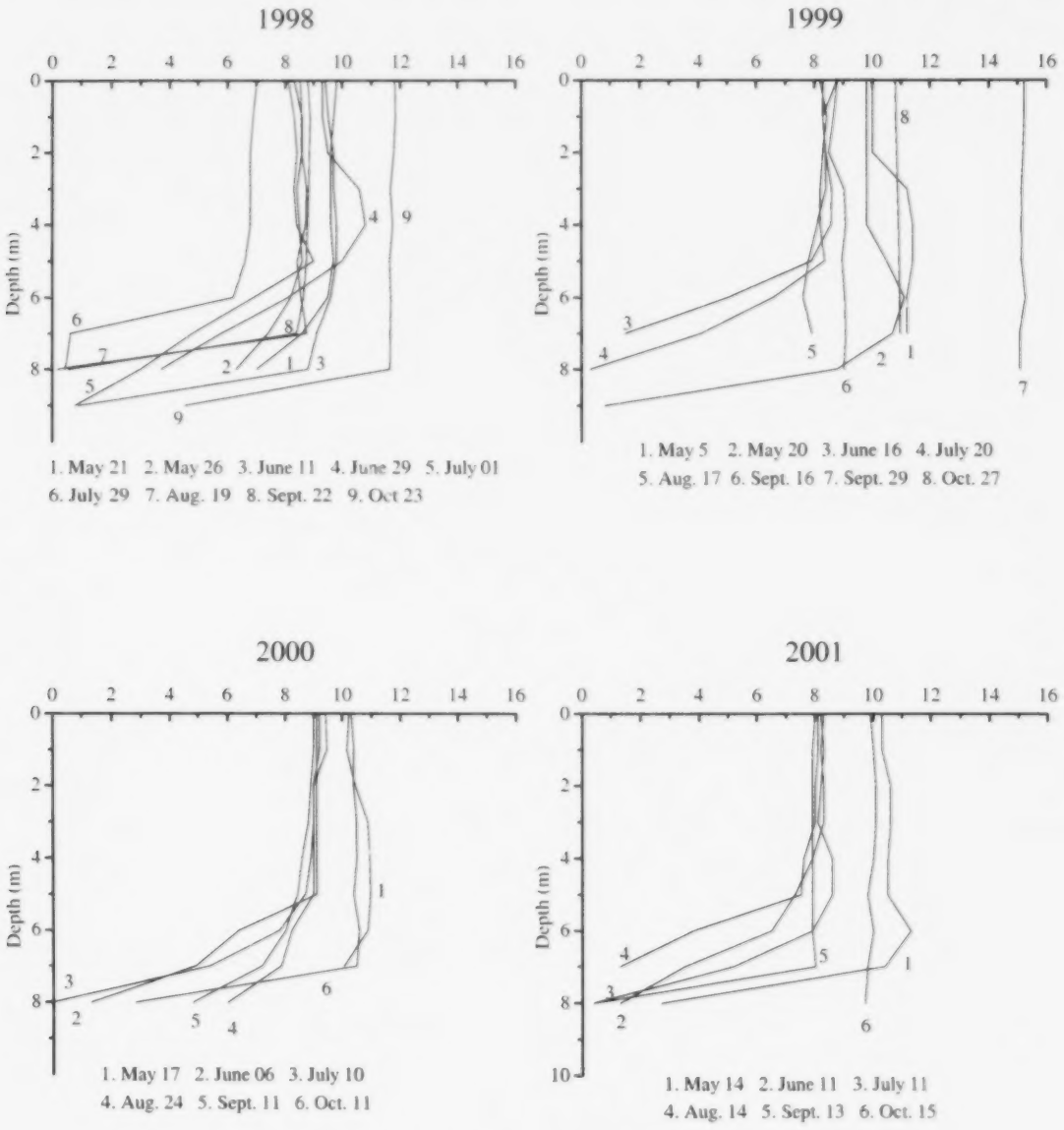
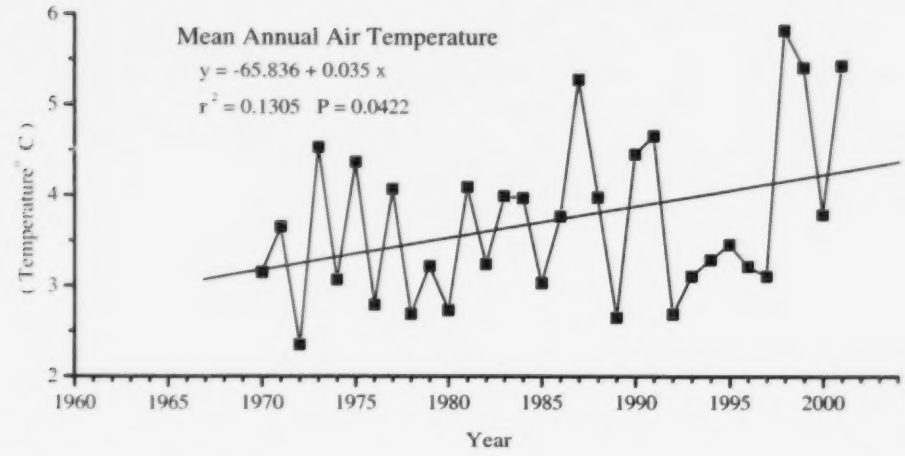
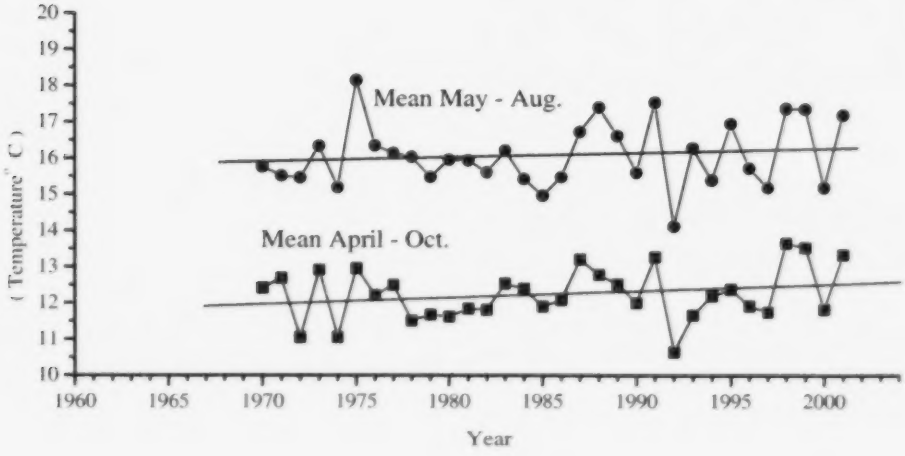

1998
1999
2000
2001
Depth (m)
1. May 21 2. May 26 3. June 11 4. June 29 5. July 01
6. July 29 7. Aug. 19 8. Sept. 22 9. Oct 23
1. May 5 2. May 20 3. June 16 4. July 20
5. Aug. 17 6. Sept. 16 7. Sept. 29 8. Oct. 27
1. May 17 2. June 06 3. July 10
4. Aug. 24 5. Sept. 11 6. Oct. 11
1. May 14 2. June 11 3. July 11
4. Aug. 14 5. Sept. 13 6. Oct. 15

Figure 10a . Long - Term changes in Sudbury airport air temperature data: Summer vs. Winter Seasons





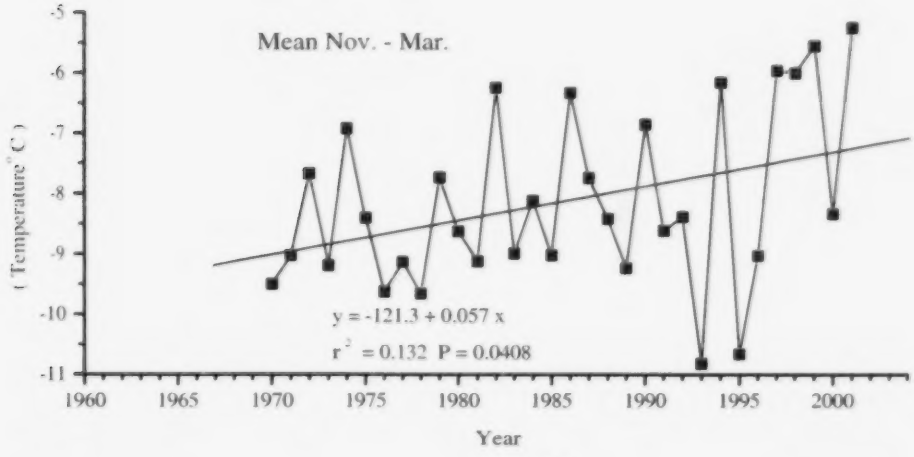
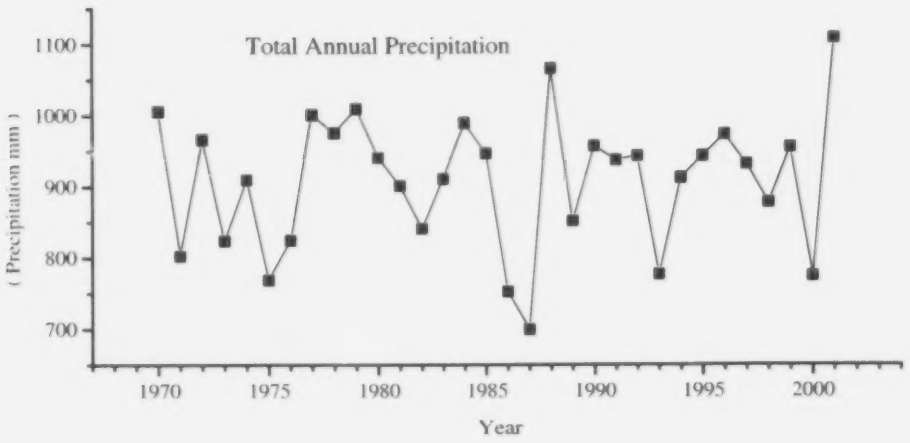
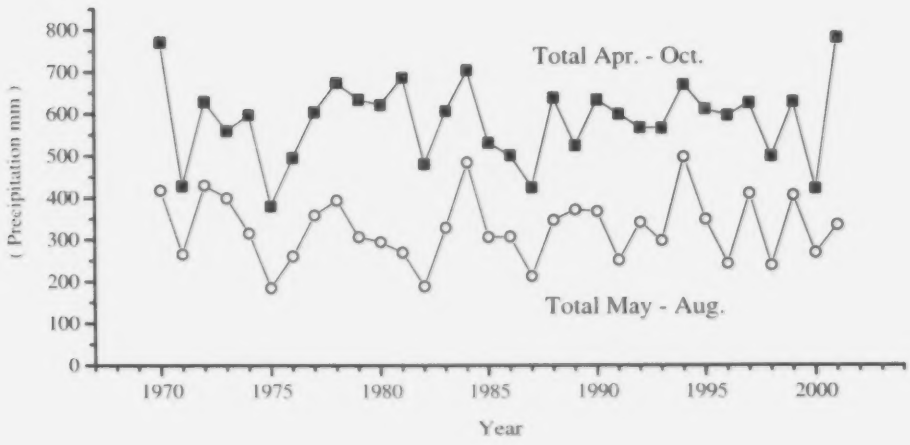


Figure 10b . Long - Term changes in Sudbury airport precipitation data
Summer vs. Winter





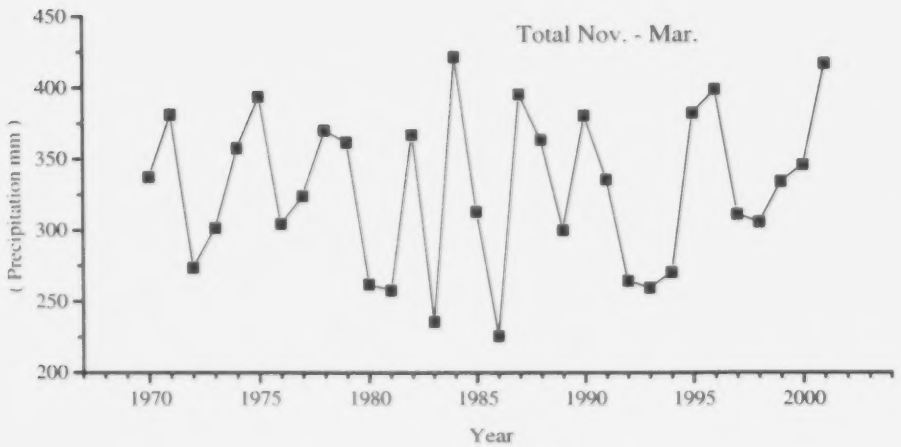
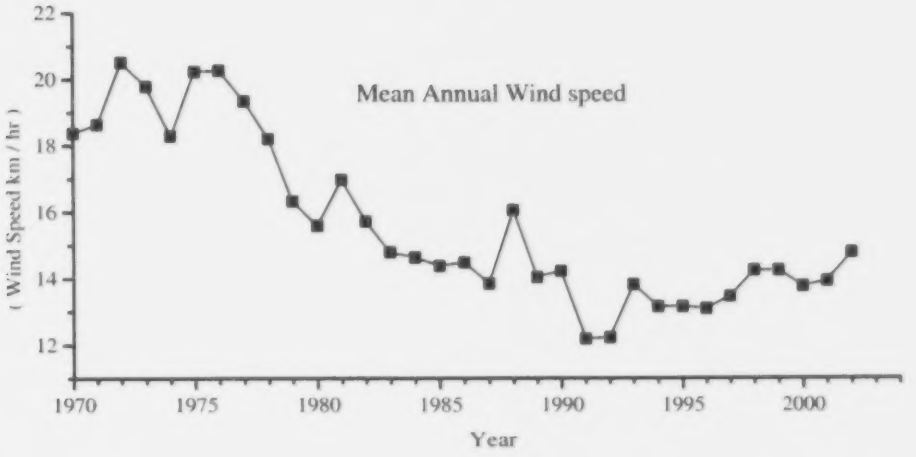
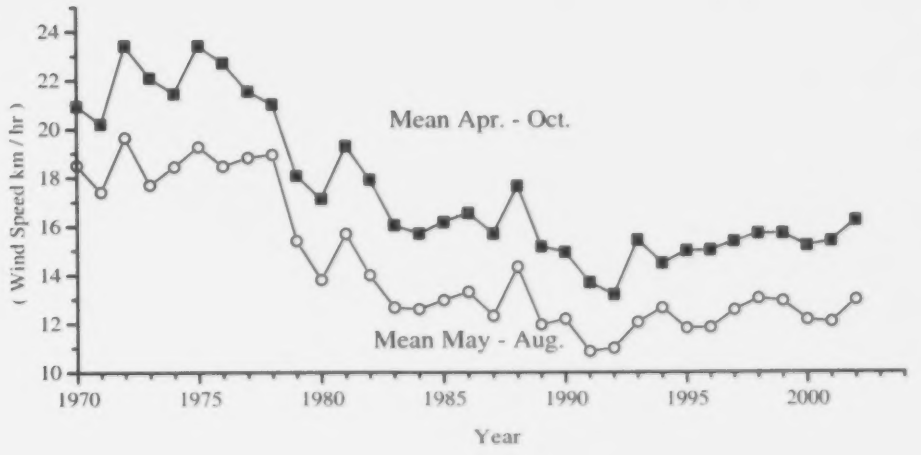


Figure 10c . Long-Term changes in Sudbury airport wind speed data
Summer vs. Winter





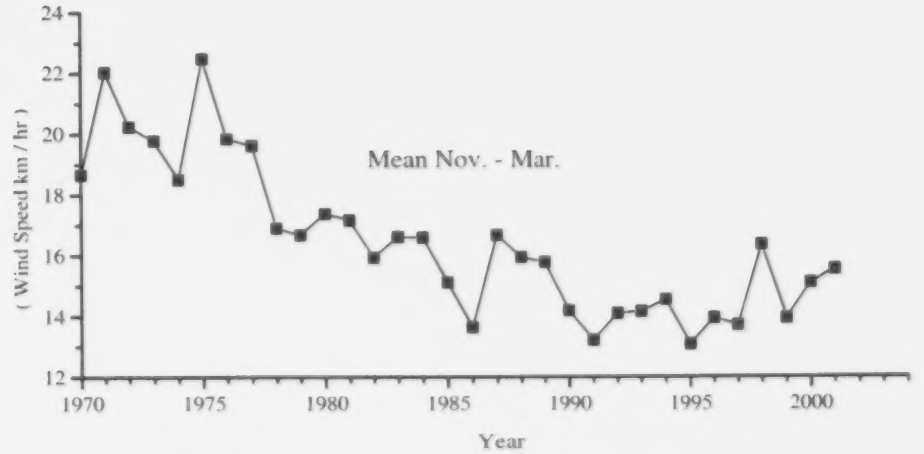
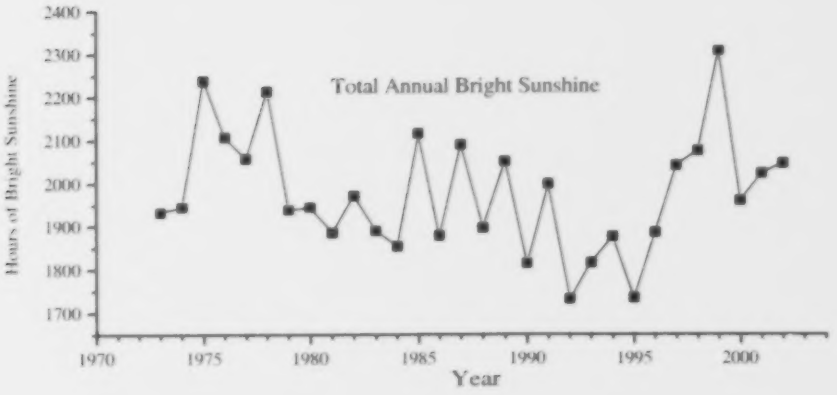
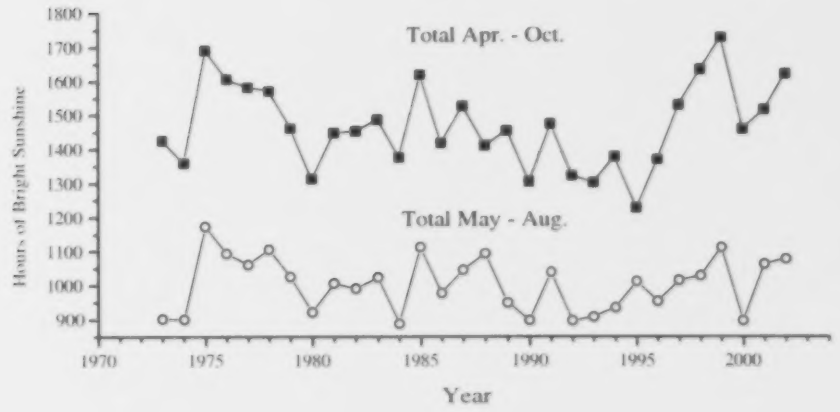
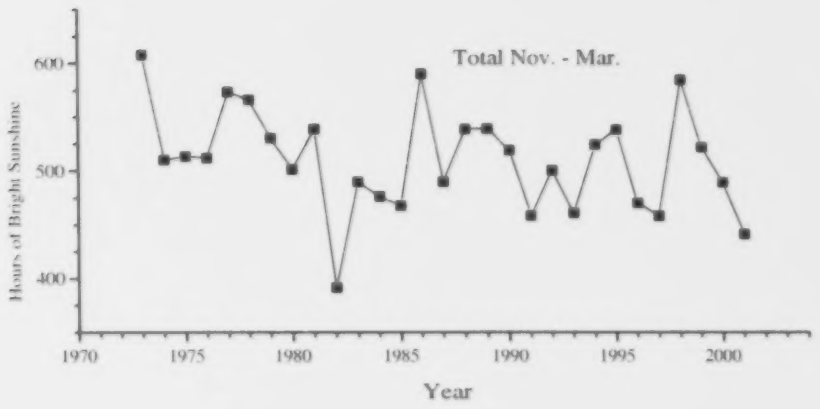


Figure 10d : Long-Term changes in Sudbury airport hours of bright sunshine data
Summer vs. Winter Season







Appendix 1: Summary of log-term changes in the protocols employed to analyze water samples in the lakes.

Analytical Method Codes 1973 - 2001

* Analytical Methods codes are supported by the MOE Laboratory Services Branch, Customer Services, Research & Reference Scientist

		ANALYTICAL			REPORTED
	PARAMETER	METHOD *	START	END	UNITS
ALKALINITY: total fixed endpoint.	ALKT	000A	5/19/75	10/15/80	$mg \cdot L^{-1}$ as $CaCO_3$
		0	5/12/81	10/21/85	$mg \cdot L^{-1}$ as $CaCO_3$
		0905T3	11/19/85	11/3/94	$mg \cdot L^{-1}$ as $CaCO_3$
		E3042A	5/11/95	8/20/97	$mg \cdot L^{-1}$ as $CaCO_3$
		E3289A	5/26/98	9/22/98	$mg \cdot L^{-1}$ as $CaCO_3$
ALKALINITY	ALKT3	0905T3	11/19/85	11/3/94	$mg \cdot L^{-1}$ as $CaCO_3$
		E3042A	5/11/95	6/20/96	$mg \cdot L^{-1}$ as $CaCO_3$
ALKALINITY	ALKTI	0	6/5/78	10/21/85	$mg \cdot L^{-1}$ as $CaCO_3$
		0905T6	11/19/85	11/3/94	$mg \cdot L^{-1}$ as $CaCO_3$
		E3042A	5/11/95	8/20/97	$mg \cdot L^{-1}$ as $CaCO_3$
ALUMINUM	ALUT	0	6/23/75	10/20/81	$\mu g \cdot L^{-1}$
		522AA5	5/12/82	5/3/83	$\mu g \cdot L^{-1}$
		0	6/1/83	10/21/85	$\mu g \cdot L^{-1}$
		005AF2	11/19/85	8/7/91	$\mu g \cdot L^{-1}$
		E3299A	5/19/92	11/3/94	$\mu g \cdot L^{-1}$
		E3300A	5/11/95	8/20/97	$\mu g \cdot L^{-1}$
ANIONS	COMPUTED	E3196A	5/13/81	10/15/01	$\mu Eq \cdot L^{-1}$
CATIONS	COMPUTED	E3196A	5/13/81	10/15/01	$\mu Eq \cdot L^{-1}$
CALCIUM	CAUR	000B	7/19/73	10/15/80	$mg \cdot L^{-1}$
		0	2/2/81	10/20/81	$mg \cdot L^{-1}$
		002BA1	5/12/82	6/25/85	$mg \cdot L^{-1}$
		0901A1	7/22/85	7/5/88	$mg \cdot L^{-1}$
		002CA1	8/2/88	11/3/94	$mg \cdot L^{-1}$
		E3249A	5/11/95	8/20/97	$mg \cdot L^{-1}$
CHLOROPHYLL a: corrected	CHLRAC	0	5/15/74	5/12/82	$mg \cdot L^{-1}$
		002CS1	5/25/82	7/3/84	$mg \cdot L^{-1}$
		002DS1	7/30/84	11/23/87	$mg \cdot L^{-1}$
		ZE002A	3/16/88	2/15/89	$mg \cdot L^{-1}$
		002DS2	4/18/89	11/3/94	$mg \cdot L^{-1}$
		E3169A	5/11/95	9/23/97	$mg \cdot L^{-1}$
CHLOROPHYLL a: total	CHLRAT	000B	6/26/73	10/15/80	$mg \cdot L^{-1}$
		0	2/2/81	5/12/82	$mg \cdot L^{-1}$
		002AS1	5/25/82	7/3/84	$mg \cdot L^{-1}$

Appendix 1: cont'd Analytical Method Codes 1973 - 2001

CHLOROPHYLL a: total	CHLRAT	002DS1	7/30/1984	6/25/1985	mg • L^{-1}
		002DS2	7/22/1985	11/23/1987	mg • L^{-1}
		ZE002A	12/7/1987	2/15/1989	mg • L^{-1}
		002DS2	3/23/1989	11/3/1994	mg • L^{-1}
		E3169A	5/11/1995	9/23/1997	mg • L^{-1}
CHLOROPHYLL b	CHLRBT	000B	6/26/73	10/15/80	mg • L^{-1}
		0	2/2/81	5/12/82	mg • L^{-1}
		002BS1	5/25/82	7/3/84	mg • L^{-1}
		002DS2	7/22/1985	7/30/1986	mg • L^{-1}
CHLORIDE	CLIDUR	000A	5/19/1975	10/15/1980	mg • L^{-1}
		0	6/9/1981	10/20/1981	mg • L^{-1}
		004AC2	5/12/1982	3/13/1986	mg • L^{-1}
		004AC1	4/7/1986	10/26/1987	mg • L^{-1}
		004BC2	11/23/1987	9/13/1993	mg • L^{-1}
		005AI0	10/28/1993	11/3/1994	mg • L^{-1}
		E3147A	5/11/1995	8/20/1997	mg • L^{-1}
CONDUCTIVITY	COND25	0	6/26/1973	10/21/1985	µmhs • cm^{-1}
		0903CM	11/19/1985	10/22/1990	µmhs • cm^{-1}
		002B12	6/3/1991	11/3/1994	µmhs • cm^{-1}
		E3024B	5/11/1995	8/20/1997	µmhs • cm^{-1}
COPPER	CUUT	000A	6/26/1973	10/15/1980	µg • L^{-1}
		0	5/12/1981	10/20/1981	µg • L^{-1}
		522AA1	5/12/1982	12/7/1983	µg • L^{-1}
		522AE2	5/21/1985	11/3/1994	µg • L^{-1}
		E3080A	5/11/1995	8/20/1996	µg • L^{-1}
		E3386A	9/13/1996	8/20/1997	µg • L^{-1}
DISSOLVED INORGANIC	DIC	0	2/2/1981	10/20/1981	mg • L^{-1}
CARBON		102AC2	5/12/1982	6/21/1982	mg • L^{-1}
		0	8/16/1982	10/21/1985	mg • L^{-1}
		1127C2	11/19/1985	11/3/1994	mg • L^{-1}
		E3028A	5/11/1995	8/20/1997	mg • L^{-1}
DISSOLVED ORGANIC	DOC	000A	5/27/1977	7/20/1977	mg • L^{-1}
CARBON		0	2/2/1981	10/20/1981	mg • L^{-1}
		102AC2	5/12/1982	11/3/1994	mg • L^{-1}
		E3370A	5/11/1995	8/20/1997	mg • L^{-1}

Appendix 1: cont'd Analytical Method Codes 1973 - 2001

IRON	FEUT	0	6/26/1973	10/20/1981	$\mu g \cdot L^{-1}$
		504AC2	5/12/1982	5/21/1985	$\mu g \cdot L^{-1}$
		522AE2	6/25/1985	6/12/1989	$\mu g \cdot L^{-1}$
		001AE5	8/8/1989	11/7/1991	$\mu g \cdot L^{-1}$
		E3296A	5/19/1992	11/3/1994	$\mu g \cdot L^{-1}$
		E3303A	5/11/1995	8/20/1997	$\mu g \cdot L^{-1}$
POTASSIUM	KKUR	0	7/19/1973	10/20/1981	$mg \cdot L^{-1}$
		002DA1	5/12/1982	6/25/1985	$mg \cdot L^{-1}$
		0905A1	7/22/1985	7/5/1988	$mg \cdot L^{-1}$
		002EA1	8/2/1988	11/3/1994	$mg \cdot L^{-1}$
POTASSIUM	KKUT	E3249A	5/11/1995	8/20/1997	$mg \cdot L^{-1}$
MAGNESIUM	MGUR	000B	7/19/1973	10/15/1980	$mg \cdot L^{-1}$
		0	2/2/1981	10/20/1981	$mg \cdot L^{-1}$
		001BA1	5/12/1982	6/25/1985	$mg \cdot L^{-1}$
		0901A1	7/22/1985	7/5/1988	$mg \cdot L^{-1}$
		001CA1	8/2/1988	11.3/1994	$mg \cdot L^{-1}$
MAGNESIUM	MGUT	E3249A	5/11/1995	8/20/1997	$mg \cdot L^{-1}$
MANGANESE	MNUT	000B	9/11/1973	10/15/1980	$\mu g \cdot L^{-1}$
		0	2/2/1981	10/20/1981	$\mu g \cdot L^{-1}$
		504AC2	5/12/1982	5/21/1985	$\mu g \cdot L^{-1}$
		522AE2	6/25/1985	7/10/1089	$\mu g \cdot L^{-1}$
		001AE5	8/81989	11/7/1991	$\mu g \cdot L^{-1}$
		E3296A	5/19/1992	11/3/1994	$\mu g \cdot L^{-1}$
		E3303A	5/11/1995	8/20/1997	$\mu g \cdot L^{-1}$
SODIUM	NAUR	0	7/19/1973	10/20/1981	$mg \cdot L^{-1}$
		002DA1	5/12/1982	5/21/1985	$mg \cdot L^{-1}$
		0905A1	7/22/1985	7/5/1988	$mg \cdot L^{-1}$
		001EA1	8/2/1988	11/3/1994	$mg \cdot L^{-1}$
SODIUM	NAUT	E3249A	5/11/1995	8/20/1997	$mg \cdot L^{-1}$
NICKEL	NIUT	000A	6/26/1973	10/15/1980	$\mu g \cdot L^{-1}$
		0	2/2/1981	10/20/1981	$\mu g \cdot L^{-1}$
		522AA2	5/12/1982	11/3/1994	$\mu g \cdot L^{-1}$
		E3080A	5/11/1995	8/20/1996	$\mu g \cdot L^{-1}$
		E3386A	9/13/1996	8/20/1997	$\mu g \cdot L^{-1}$

Appendix 1: cont'd Analytical Method Codes 1973 - 2001

NITROGEN: AMONIA,	NNHTFR	000B	7/19/1973	10/15/1980	$\mu g \cdot L^{-1}$
+ AMMONIUM		0	2/2/1981	10/21/1985	$\mu g \cdot L^{-1}$
		1524C2	11/19/1985	11/3/1994	$\mu g \cdot L^{-1}$
NITROGEN: AMONIA,	NNHTUR	E3374A	5/1/11995	8/20/1997	$\mu g \cdot L^{-1}$
+ AMMONIUM					
NITROGEN:	NNOTFR	000B	6/26/1973	10/15/1980	$\mu g \cdot L^{-1}$
NITRATE+NITRITE		0	2/2/1981	10/21/1985	$\mu g \cdot L^{-1}$
		1525C2	11/19/1985	11/3/1994	$\mu g \cdot L^{-1}$
NITROGEN:	NNOTUR	E3374A	5/11/1995	8/20/1997	$\mu g \cdot L^{-1}$
NITRATE+NITRITE					
NITROGEN:	NNTKFR	000A	5/10/1979	2/28/1980	$\mu g \cdot L^{-1}$
TOTAL KJELDAHL					
NITROGEN:	NNTKUR	000B	6/26/1973	10/15/1980	$\mu g \cdot L^{-1}$
TOTAL KJELDAHL		0	2/2/1981	5/7/1984	$\mu g \cdot L^{-1}$
		004AC2	6/4/1984	11/3/1994	$\mu g \cdot L^{-1}$
		E3367A	5/11/1995	8/20/1997	$\mu g \cdot L^{-1}$
pH	PH	0	6/26/1973	10/21/1985	(H^+)
		0902PH	11/19/1985	11/3/1994	(H^+)
		E3042A	5/11/1995	8/20/1997	(H^+)
TOTAL PHOSPHORUS	PPUT	000B	6/26/1973	10/15/1980	$\mu g \cdot L^{-1}$
		0	2/2/1981	10/21/1985	$\mu g \cdot L^{-1}$
		E3036A	5/11/1995	9/23/1997	$\mu g \cdot L^{-1}$
TOTAL PHOSPHORUS	PPUT1	5926C2	11/19/1985	3/13/1986	$\mu g \cdot L^{-1}$
SILICON:	SIO3UR	000E	7/19/1973	10/15/1980	$mg \cdot L^{-1}$
REACTIVE SILICATE		0	2/2/1981	10/20/1981	$mg \cdot L^{-1}$
		001BC2	5/12/1982	3/13/1986	$mg \cdot L^{-1}$
		001BC1	4/7/1986	11/3/1994	$mg \cdot L^{-1}$
		E3370A	5/11/1995	8/20/1997	$mg \cdot L^{-1}$
SULPHATE	SSO4UR	000B	6/23/1980	10/15/1980	$mg \cdot L^{-1}$
		0	2/2/1981	10/20/1981	$mg \cdot L^{-1}$
		003AI0	5/12/1982	11/3/1994	$mg \cdot L^{-1}$
		E3147A	5/11/1995	8/20/1997	$mg \cdot L^{-1}$
ZINC	ZNUT	000A	6/26/1973	10/15/1980	$\mu g \cdot L^{-1}$
		0	2/2/1981	10/20/1981	$\mu g \cdot L^{-1}$
		522AA2	5/12/1982	5/3/1983	$\mu g \cdot L^{-1}$
		0	6/1/1983	10/21/1985	$\mu g \cdot L^{-1}$
		001PP2	11/19/1985	12/12/1985	$\mu g \cdot L^{-1}$

Appendix 1: cont'd Analytical Method Codes 1973 - 2001

ZINC cont'd	ZNUT	522AE2	1/15/1986	7/19/1993	$\mu g \cdot L^{-1}$
		005AF2	9/13/1993	9/13/1993	$\mu g \cdot L^{-1}$
		522AE2	10/28/1993	11/3/1994	$\mu g \cdot L^{-1}$
		E3080A	5/11/1995	8/20/1996	$\mu g \cdot L^{-1}$
		E3386A	9/13/1996	8/20/1997	$\mu g \cdot L^{-1}$

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2a. Long-term monthly mean temperature (^{o} C) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1970	1	-15.89		1974	1	-12.47		1978	1	-15.30
1970	2	-14.01		1974	2	-14.63		1978	2	-12.90
1970	3	-6.59		1974	3	-7.28		1978	3	-7.33
1970	4	2.96		1974	4	2.65		1978	4	0.75
1970	5	9.01		1974	5	8.07		1978	5	13.78
1970	6	16.07		1974	6	15.94		1978	6	14.64
1970	7	19.47		1974	7	18.86		1978	7	18.31
1970	8	18.49		1974	8	17.87		1978	8	17.40
1970	9	12.60		1974	9	10.10		1978	9	10.97
1970	10	8.23		1974	10	3.84		1978	10	4.63
1970	11	-0.56		1974	11	-0.50		1978	11	-2.13
1970	12	-12.01		1974	12	-5.58		1978	12	-10.50
1971	1	-16.06		1975	1	-11.34		1979	1	-14.75
1971	2	-11.45		1975	2	-9.79		1979	2	-17.10
1971	3	-7.44		1975	3	-7.41		1979	3	-3.82
1971	4	1.27		1975	4	-0.05		1979	4	2.37
1971	5	10.26		1975	5	15.06		1979	5	10.51
1971	6	17.82		1975	6	17.84		1979	6	15.94
1971	7	17.31		1975	7	20.59		1979	7	19.51
1971	8	16.66		1975	8	19.07		1979	8	15.97
1971	9	15.13		1975	9	11.11		1979	9	12.37
1971	10	10.34		1975	10	7.07		1979	10	5.01
1971	11	-1.61		1975	11	0.89		1979	11	-0.63
1971	12	-8.45		1975	12	-10.63		1979	12	-6.71
1972	1	-11.90		1976	1	-16.40		1980	1	-11.65
1972	2	-13.87		1976	2	-9.54		1980	2	-13.31
1972	3	-9.33		1976	3	-6.33		1980	3	-6.38
1972	4	0.14		1976	4	4.53		1980	4	3.77
1972	5	12.34		1976	5	9.67		1980	5	12.43
1972	6	14.82		1976	6	18.98		1980	6	13.39
1972	7	18.35		1976	7	18.72		1980	7	18.92
1972	8	16.30		1976	8	18.00		1980	8	19.08
1972	9	11.73		1976	9	11.80		1980	9	10.87
1972	10	3.67		1976	10	3.71		1980	10	2.85
1972	11	-2.22		1976	11	-4.05		1980	11	-2.57
1972	12	-11.78		1976	12	-15.59		1980	12	-14.69
1973	1	-10.66		1977	1	-16.59		1981	1	-15.53
1973	2	-13.70		1977	2	-10.70		1981	2	-6.89
1973	3	-0.00		1977	3	-1.23		1981	3	-3.46
1973	4	3.68		1977	4	4.60		1981	4	3.96
1973	5	9.62		1977	5	14.43		1981	5	9.96
1973	6	16.67		1977	6	15.04		1981	6	15.28
1973	7	19.25		1977	7	19.37		1981	7	19.91
1973	8	19.77		1977	8	15.70		1981	8	18.61
1973	9	12.41		1977	9	12.55		1981	9	11.15
1973	10	8.95		1977	10	5.76		1981	10	3.97
1973	11	-1.69		1977	11	-0.12		1981	11	-0.18
1973	12	-9.89		1977	12	-10.02		1981	12	-7.72

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2a. cont'd: Long-term monthly mean temperature (^{o} C) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month
1982	1	-19.23		1986	1	-13.77		1990	1
1982	2	-12.41		1986	2	-11.56		1990	2
1982	3	-6.11		1986	3	-4.56		1990	3
1982	4	0.24		1986	4	6.14		1990	4
1982	5	13.85		1986	5	12.89		1990	5
1982	6	13.85		1986	6	14.01		1990	6
1982	7	19.06		1986	7	18.57		1990	7
1982	8	15.63		1986	8	16.45		1990	8
1982	9	12.29		1986	9	11.28		1990	9
1982	10	7.73		1986	10	5.18		1990	10
1982	11	-0.73		1986	11	-3.00		1990	11
1982	12	-5.33		1986	12	-6.41		1990	12
1983	1	-11.54		1987	1	-9.90		1991	1
1983	2	-9.30		1987	2	-9.64		1991	2
1983	3	-4.34		1987	3	-2.69		1991	3
1983	4	2.46		1987	4	7.47		1991	4
1983	5	7.49		1987	5	11.46		1991	5
1983	6	17.26		1987	6	17.42		1991	6
1983	7	20.34		1987	7	20.28		1991	7
1983	8	19.71		1987	8	17.75		1991	8
1983	9	14.32		1987	9	13.77		1991	9
1983	10	6.12		1987	10	4.28		1991	10
1983	11	-1.05		1987	11	-1.13		1991	11
1983	12	-13.66		1987	12	-5.78		1991	12
1984	1	-16.20		1988	1	-11.71		1992	1
1984	2	-6.18		1988	2	-13.48		1992	2
1984	3	-7.88		1988	3	-6.61		1992	3
1984	4	6.32		1988	4	3.31		1992	4
1984	5	8.24		1988	5	12.94		1992	5
1984	6	16.13		1988	6	15.75		1992	6
1984	7	18.77		1988	7	21.93		1992	7
1984	8	18.54		1988	8	18.99		1992	8
1984	9	10.90		1988	9	12.48		1992	9
1984	10	7.76		1988	10	4.06		1992	10
1984	11	-0.62		1988	11	0.42		1992	11
1984	12	-8.19		1988	12	-10.33		1992	12
1985	1	-15.33		1989	1	-10.37		1993	1
1985	2	-11.01		1989	2	-13.63		1993	2
1985	3	-5.44		1989	3	-8.18		1993	3
1985	4	3.03		1989	4	1.34		1993	4
1985	5	11.14		1989	5	12.11		1993	5
1985	6	13.98		1989	6	15.93		1993	6
1985	7	17.57		1989	7	20.74		1993	7
1985	8	17.14		1989	8	17.72		1993	8
1985	9	13.58		1989	9	13.06		1993	9
1985	10	6.86		1989	10	6.72		1993	10
1985	11	-2.06		1989	11	-5.12		1993	11
1985	12	-13.16		1989	12	-18.54		1993	12

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2a. cont'd: Long-term monthly mean temperature (° C) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month
1994	1	-21.88		1998	1	-10.71		2002	1
1994	2	-14.90		1998	2	-5.05		2002	2
1994	3	-4.94		1998	3	-4.25		2002	3
1994	4	2.51		1998	4	6.09			
1994	5	10.01		1998	5	14.73			
1994	6	17.21		1998	6	16.58			
1994	7	18.54		1998	7	19.12			
1994	8	15.80		1998	8	19.06			
1994	9	13.49		1998	9	13.37			
1994	10	7.73		1998	10	6.59			
1994	11	0.54		1998	11	0.70			
1994	12	-4.69		1998	12	-6.28			
1995	1	-9.39		1999	1	-13.27			
1995	2	-13.92		1999	2	-7.49			
1995	3	-3.28		1999	3	-3.64			
1995	4	0.52		1999	4	5.32			
1995	5	10.57		1999	5	14.14			
1995	6	18.69		1999	6	17.96			
1995	7	19.22		1999	7	20.34			
1995	8	19.33		1999	8	16.97			
1995	9	10.88		1999	9	14.88			
1995	10	7.40		1999	10	5.13			
1995	11	-6.22		1999	11	1.09			
1995	12	-12.24		1999	12	-6.43			
1996	1	-14.59		2000	1	-13.90			
1996	2	-12.45		2000	2	-7.94			
1996	3	-7.78		2000	3	-0.55			
1996	4	0.29		2000	4	3.61			
1996	5	9.51		2000	5	11.49			
1996	6	17.34		2000	6	14.88			
1996	7	17.82		2000	7	17.33			
1996	8	18.19		2000	8	17.05			
1996	9	14.51		2000	9	11.14			
1996	10	5.75		2000	10	7.23			
1996	11	-3.11		2000	11	-1.00			
1996	12	-6.91		2000	12	-13.81			
1997	1	-16.05		2001	1	-10.53			
1997	2	-11.75		2001	2	-11.78			
1997	3	-7.35		2001	3	-4.53			
1997	4	2.84		2001	4	5.01			
1997	5	7.45		2001	5	12.83			
1997	6	18.63		2001	6	17.45			
1997	7	18.60		2001	7	18.53			
1997	8	16.03		2001	8	19.96			
1997	9	12.41		2001	9	12.75			
1997	10	6.25		2001	10	6.75			
1997	11	-2.27		2001	11	2.55			
1997	12	-7.49		2001	12	-3.66			

Appendix 2: Summarized Temperature (°C)

Mean annual and in summer, vs. winter seasons

YEAR	Annual	May - Aug.	Apr. - Oct.	Nov. - Mar.
1970	3.15	15.76	12.4	-9.5
1971	3.65	15.51	12.7	-9.0
1972	2.35	15.45	11.1	-7.7
1973	4.53	16.33	12.9	-9.2
1974	3.07	15.19	11.0	-6.9
1975	4.37	18.14	13.0	-8.4
1976	2.79	16.34	12.2	-9.6
1977	4.07	16.13	12.5	-9.1
1978	2.69	16.03	11.5	-9.7
1979	3.22	15.48	11.7	-7.7
1980	2.73	15.95	11.6	-8.6
1981	4.09	15.94	11.8	-9.1
1982	3.24	15.60	11.8	-6.2
1983	3.99	16.20	12.5	-9.0
1984	3.97	15.42	12.4	-8.1
1985	3.03	14.96	11.9	-9.0
1986	3.77	15.48	12.1	-6.3
1987	5.28	16.73	13.2	-7.7
1988	3.98	17.40	12.8	-8.4
1989	2.65	16.62	12.5	-9.2
1990	4.46	15.60	12.0	-6.9
1991	4.66	17.53	13.3	-8.6
1992	2.69	14.12	10.7	-8.4
1993	3.11	16.28	11.7	-10.8
1994	3.29	15.39	12.2	-6.1
1995	3.46	16.95	12.4	-10.7
1996	3.22	15.72	11.9	-9.0
1997	3.11	15.18	11.7	-6.0
1998	5.83	17.37	13.6	-6.0
1999	5.42	17.35	13.5	-5.5
2000	3.79	15.19	11.8	-8.3
2001	5.44	17.19	13.3	-5.2

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2b Long-term Precipitation (mm) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1970	1	37.3		1974	1	83.3		1978	1	83.6
1970	2	31.2		1974	2	76.2		1978	2	14.3
1970	3	40.9		1974	3	31.5		1978	3	42.4
1970	4	50.4		1974	4	71.3		1978	4	51.1
1970	5	132.7		1974	5	85.9		1978	5	70.7
1970	6	94.9		1974	6	85.7		1978	6	72.2
1970	7	145.9		1974	7	78.7		1978	7	92.3
1970	8	43.9		1974	8	64.9		1978	8	157.8
1970	9	236.4		1974	9	104.2		1978	9	160.7
1970	10	67.1		1974	10	106.3		1978	10	68.8
1970	11	67.0		1974	11	54.0		1978	11	60.6
1970	12	58.0		1974	12	67.7		1978	12	100.5
1971	1	71.8		1975	1	117.2		1979	1	68.0
1971	2	90.2		1975	2	53.2		1979	2	36.0
1971	3	50.3		1975	3	65.5		1979	3	105.1
1971	4	32.2		1975	4	33.6		1979	4	176.8
1971	5	73.7		1975	5	71.9		1979	5	48.7
1971	6	40.5		1975	6	55.0		1979	6	79.1
1971	7	95.0		1975	7	35.8		1979	7	80.9
1971	8	55.5		1975	8	21.8		1979	8	97.5
1971	9	69.1		1975	9	76.1		1979	9	54.0
1971	10	61.4		1975	10	85.3		1979	10	96.7
1971	11	69.7		1975	11	110.0		1979	11	100.1
1971	12	93.3		1975	12	43.8		1979	12	66.1
1972	1	73.1		1976	1	52.9		1980	1	95.1
1972	2	79.2		1976	2	85.7		1980	2	21.7
1972	3	65.8		1976	3	101.4		1980	3	78.7
1972	4	60.8		1976	4	17.6		1980	4	111.4
1972	5	45.6		1976	5	92.1		1980	5	61.9
1972	6	111.6		1976	6	44.2		1980	6	64.4
1972	7	78.2		1976	7	48.7		1980	7	68.0
1972	8	194.0		1976	8	75.3		1980	8	100.0
1972	9	102.2		1976	9	158.7		1980	9	148.1
1972	10	36.4		1976	10	57.3		1980	10	67.0
1972	11	31.4		1976	11	44.6		1980	11	68.0
1972	12	87.6		1976	12	46.1		1980	12	56.5
1973	1	46.5		1977	1	44.6		1981	1	16.0
1973	2	29.9		1977	2	71.8		1981	2	83.6
1973	3	78.2		1977	3	97.3		1981	3	37.8
1973	4	41.7		1977	4	49.4		1981	4	130.5
1973	5	114.2		1977	5	22.1		1981	5	57.0
1973	6	84.9		1977	6	74.6		1981	6	112.2
1973	7	99.5		1977	7	156.7		1981	7	30.8
1973	8	100.8		1977	8	104.3		1981	8	68.7
1973	9	27.6		1977	9	137.9		1981	9	177.1
1973	10	90.2		1977	10	58.4		1981	10	109.4
1973	11	61.0		1977	11	96.9		1981	11	36.9
1973	12	49.5		1977	12	86.8		1981	12	41.2

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2b cont'd: Long-term Precipitation (mm) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1982	1	93.1		1986	1	29.4		1990	1	82.1
1982	2	27.6		1986	2	16.2		1990	2	35.4
1982	3	59.0		1986	3	102.7		1990	3	31.8
1982	4	60.0		1986	4	26.3		1990	4	49.1
1982	5	27.2		1986	5	76.4		1990	5	142.7
1982	6	64.7		1986	6	93.0		1990	6	146.6
1982	7	32.7		1986	7	85.8		1990	7	38.2
1982	8	63.8		1986	8	51.9		1990	8	38.8
1982	9	134.4		1986	9	90.8		1990	9	72.7
1982	10	97.0		1986	10	76.5		1990	10	144.2
1982	11	87.0		1986	11	42.6		1990	11	120.5
1982	12	94.4		1986	12	61.3		1990	12	54.4
1983	1	58.4		1987	1	30.9		1991	1	50.0
1983	2	34.7		1987	2	44.6		1991	2	35.2
1983	3	92.4		1987	3	46.2		1991	3	120.4
1983	4	77.9		1987	4	46.8		1991	4	72.0
1983	5	137.6		1987	5	70.0		1991	5	73.0
1983	6	38.4		1987	6	58.2		1991	6	22.5
1983	7	41.2		1987	7	45.4		1991	7	109.8
1983	8	111.1		1987	8	38.7		1991	8	44.9
1983	9	97.9		1987	9	93.8		1991	9	117.5
1983	10	102.2		1987	10	70.9		1991	10	158.9
1983	11	56.9		1987	11	80.4		1991	11	59.1
1983	12	62.4		1987	12	73.6		1991	12	73.5
1984	1	36.8		1988	1	70.2		1992	1	61.5
1984	2	56.0		1988	2	75.7		1992	2	52.2
1984	3	23.6		1988	3	95.6		1992	3	89.2
1984	4	49.4		1988	4	77.0		1992	4	45.7
1984	5	101.1		1988	5	90.6		1992	5	48.0
1984	6	178.0		1988	6	36.7		1992	6	90.4
1984	7	61.1		1988	7	29.8		1992	7	84.5
1984	8	143.2		1988	8	188.1		1992	8	117.2
1984	9	96.8		1988	9	91.5		1992	9	114.5
1984	10	73.7		1988	10	124.0		1992	10	65.2
1984	11	89.3		1988	11	120.0		1992	11	99.6
1984	12	80.2		1988	12	66.2		1992	12	74.6
1985	1	50.1		1989	1	84.7		1993	1	55.2
1985	2	107.7		1989	2	13.3		1993	2	12.0
1985	3	94.4		1989	3	79.3		1993	3	23.0
1985	4	88.5		1989	4	58.2		1993	4	92.2
1985	5	52.2		1989	5	71.9		1993	5	127.6
1985	6	42.0		1989	6	160.9		1993	6	40.6
1985	7	148.3		1989	7	56.4		1993	7	55.2
1985	8	63.0		1989	8	81.6		1993	8	73.2
1985	9	69.2		1989	9	25.6		1993	9	79.1
1985	10	66.7		1989	10	69.0		1993	10	96.4
1985	11	90.8		1989	11	104.6		1993	11	72.0
1985	12	73.7		1989	12	46.1		1993	12	50.1

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2b cont'd: Long-term Precipitation (mm) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1994	1	59.3		1998	1	69.1		2002	1	30.5
1994	2	40.0		1998	2	21.3		2002	2	126.4
1994	3	38.2		1998	3	150.5		2002	3	97.4
1994	4	36.8		1998	4	55.3				
1994	5	102.4		1998	5	77.6				
1994	6	111.0		1998	6	78.6				
1994	7	144.6		1998	7	30.1				
1994	8	138.0		1998	8	51.3				
1994	9	64.2		1998	9	142.0				
1994	10	71.7		1998	10	63.3				
1994	11	75.2		1998	11	82.7				
1994	12	30.4		1998	12	55.7				
1995	1	85.1		1999	1	100.7				
1995	2	28.5		1999	2	54.9				
1995	3	51.4		1999	3	11.6				
1995	4	107.6		1999	4	23.3				
1995	5	133.4		1999	5	78.5				
1995	6	40.4		1999	6	122.1				
1995	7	101.4		1999	7	106.0				
1995	8	72.2		1999	8	98.1				
1995	9	62.2		1999	9	130.2				
1995	10	93.0		1999	10	68.5				
1995	11	112.0		1999	11	68.2				
1995	12	54.9		1999	12	92.5				
1996	1	92.5		2000	1	77.6				
1996	2	87.3		2000	2	56.7				
1996	3	35.5		2000	3	38.9				
1996	4	119.9		2000	4	22.4				
1996	5	37.2		2000	5	65.2				
1996	6	56.4		2000	6	66.1				
1996	7	90.5		2000	7	62.4				
1996	8	57.6		2000	8	73.7				
1996	9	157.6		2000	9	79.0				
1996	10	75.8		2000	10	51.8				
1996	11	50.8		2000	11	106.7				
1996	12	111.7		2000	12	73.6				
1997	1	120.4		2001	1	61.3				
1997	2	77.8		2001	2	70.0				
1997	3	38.2		2001	3	34.2				
1997	4	54.9		2001	4	79.8				
1997	5	69.8		2001	5	145.1				
1997	6	61.7		2001	6	75.4				
1997	7	108.7		2001	7	33.2				
1997	8	168.2		2001	8	79.4				
1997	9	103.5		2001	9	193.1				
1997	10	57.5		2001	10	173.6				
1997	11	43.6		2001	11	109.6				
1997	12	26.7		2001	12	52.8				

Appendix 2: Summarized Precipitation (mm)

Total annual and in summer, vs. winter seasons

Year	Annual	May-Aug.	Apr. - Oct.	Nov. - Mar.
1970	1005.7	417.4	771.3	337.3
1971	802.7	264.7	427.4	381.1
1972	965.9	429.4	628.8	273.6
1973	824.0	399.4	558.9	301.5
1974	909.7	315.2	597.0	357.6
1975	769.2	184.5	379.5	393.8
1976	824.6	260.3	493.9	304.4
1977	1000.8	357.7	603.4	324.0
1978	975.0	393.0	673.6	370.2
1979	1009.0	306.2	633.7	361.7
1980	940.8	294.3	620.8	261.9
1981	901.2	268.7	685.7	257.8
1982	840.9	188.4	479.8	366.9
1983	911.1	328.3	606.3	235.7
1984	989.2	483.4	703.3	421.7
1985	946.6	305.5	529.9	312.8
1986	752.9	307.1	500.7	225.6
1987	699.5	212.3	423.8	395.5
1988	1065.4	345.2	637.7	363.5
1989	851.6	370.8	523.6	300.0
1990	956.5	366.3	632.3	380.5
1991	936.8	250.2	598.6	335.5
1992	942.6	340.1	565.5	264.4
1993	776.6	296.6	564.3	259.6
1994	911.8	496.0	668.7	270.6
1995	942.1	347.4	610.2	382.2
1996	972.8	241.7	595.0	398.9
1997	931.0	408.4	624.3	311.2
1998	877.5	237.6	498.2	305.6
1999	954.6	404.7	626.7	333.9
2000	774.1	267.4	420.6	345.8
2001	1107.5	333.1	779.6	416.7

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2c: Long-term Wind speed (km) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1970	1	15.53		1974	1	17.00		1978	1	21.88
1970	2	21.61		1974	2	17.42		1978	2	17.35
1970	3	17.88		1974	3	21.67		1978	3	18.56
1970	4	21.33		1974	4	20.66		1978	4	20.71
1970	5	22.03		1974	5	18.88		1978	5	20.64
1970	6	19.26		1974	6	20.72		1978	6	19.91
1970	7	17.31		1974	7	17.09		1978	7	17.50
1970	8	15.45		1974	8	17.08		1978	8	17.69
1970	9	17.30		1974	9	16.09		1978	9	15.84
1970	10	16.01		1974	10	17.97		1978	10	16.29
1970	11	20.41		1974	11	17.06		1978	11	17.33
1970	12	16.40		1974	12	17.90		1978	12	14.94
1971	1	17.74		1975	1	18.61		1979	1	18.57
1971	2	20.98		1975	2	16.43		1979	2	16.66
1971	3	17.79		1975	3	22.51		1979	3	16.95
1971	4	18.86		1975	4	23.28		1979	4	16.90
1971	5	18.81		1975	5	18.36		1979	5	16.18
1971	6	15.55		1975	6	19.50		1979	6	17.31
1971	7	18.54		1975	7	20.14		1979	7	14.38
1971	8	16.75		1975	8	19.08		1979	8	13.72
1971	9	16.28		1975	9	19.52		1979	9	15.91
1971	10	18.93		1975	10	21.53		1979	10	15.33
1971	11	20.74		1975	11	22.65		1979	11	16.50
1971	12	22.84		1975	12	21.23		1979	12	17.72
1972	1	24.15		1976	1	21.90		1980	1	16.14
1972	2	19.17		1976	2	22.84		1980	2	16.21
1972	3	23.24		1976	3	23.72		1980	3	16.80
1972	4	18.95		1976	4	22.81		1980	4	14.98
1972	5	19.84		1976	5	19.80		1980	5	14.44
1972	6	21.52		1976	6	17.24		1980	6	15.27
1972	7	18.38		1976	7	19.39		1980	7	13.15
1972	8	18.83		1976	8	17.45		1980	8	12.38
1972	9	20.16		1976	9	18.70		1980	9	15.99
1972	10	22.97		1976	10	19.92		1980	10	16.97
1972	11	19.56		1976	11	19.37		1980	11	17.99
1972	12	19.37		1976	12	20.18		1980	12	16.92
1973	1	21.72		1977	1	19.76		1981	1	15.32
1973	2	18.21		1977	2	21.22		1981	2	19.23
1973	3	22.35		1977	3	18.70		1981	3	17.34
1973	4	25.51		1977	4	20.05		1981	4	21.09
1973	5	19.08		1977	5	19.63		1981	5	18.75
1973	6	17.72		1977	6	18.70		1981	6	16.73
1973	7	18.03		1977	7	18.81		1981	7	13.95
1973	8	15.96		1977	8	18.17		1981	8	13.35
1973	9	17.99		1977	9	17.38		1981	9	15.00
1973	10	18.17		1977	10	19.47		1981	10	18.28
1973	11	20.61		1977	11	20.28		1981	11	16.91
1973	12	22.18		1977	12	20.00		1981	12	17.28

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2c cont'd: Long-term Wind speed (km) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1982	1	18.06		1986	1	16.60		1990	1	17.94
1982	2	14.04		1986	2	12.71		1990	2	17.41
1982	3	19.50		1986	3	16.74		1990	3	12.45
1982	4	19.90		1986	4	17.85		1990	4	16.32
1982	5	13.37		1986	5	14.99		1990	5	13.91
1982	6	13.60		1986	6	14.88		1990	6	13.27
1982	7	14.55		1986	7	11.81		1990	7	10.67
1982	8	14.49		1986	8	11.55		1990	8	10.92
1982	9	14.78		1986	9	14.29		1990	9	13.46
1982	10	15.23		1986	10	13.75		1990	10	13.67
1982	11	14.73		1986	11	15.30		1990	11	15.02
1982	12	16.47		1986	12	13.48		1990	12	15.73
1983	1	16.71		1987	1	12.78		1991	1	13.10
1983	2	13.61		1987	2	12.56		1991	2	12.38
1983	3	18.08		1987	3	14.06		1991	3	14.65
1983	4	15.38		1987	4	16.85		1991	4	14.10
1983	5	14.15		1987	5	13.62		1991	5	13.08
1983	6	12.22		1987	6	10.68		1991	6	11.05
1983	7	13.43		1987	7	11.43		1991	7	9.22
1983	8	10.83		1987	8	13.55		1991	8	10.05
1983	9	13.18		1987	9	14.09		1991	9	10.00
1983	10	15.11		1987	10	15.65		1991	10	13.69
1983	11	19.57		1987	11	15.71		1991	11	11.94
1983	12	15.36		1987	12	15.15		1991	12	12.95
1984	1	14.87		1988	1	17.93		1992	1	13.54
1984	2	16.85		1988	2	17.07		1992	2	13.49
1984	3	16.34		1988	3	17.48		1992	3	14.11
1984	4	18.03		1988	4	15.50		1992	4	13.71
1984	5	15.13		1988	5	16.42		1992	5	15.85
1984	6	13.30		1988	6	17.27		1992	6	11.30
1984	7	11.53		1988	7	11.77		1992	7	7.77
1984	8	10.43		1988	8	11.91		1992	8	9.06
1984	9	13.10		1988	9	16.14		1992	9	10.76
1984	10	12.14		1988	10	17.14		1992	10	9.83
1984	11	17.52		1988	11	18.22		1992	11	12.01
1984	12	16.45		1988	12	15.86		1992	12	15.38
1985	1	13.94		1989	1	16.99		1993	1	14.21
1985	2	16.03		1989	2	14.16		1993	2	14.75
1985	3	18.97		1989	3	14.47		1993	3	14.08
1985	4	14.65		1989	4	13.52		1993	4	15.84
1985	5	14.65		1989	5	14.24		1993	5	12.37
1985	6	13.84		1989	6	12.67		1993	6	12.19
1985	7	11.93		1989	7	10.86		1993	7	12.11
1985	8	11.43		1989	8	10.08		1993	8	11.51
1985	9	13.47		1989	9	13.95		1993	9	13.91
1985	10	14.28		1989	10	16.40		1993	10	16.08
1985	11	16.62		1989	11	17.74		1993	11	15.19
1985	12	12.91		19897	12	13.37		1993	12	13.68

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2c cont'd: Long-term Wind speed (km) changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1994	1	14.57		1998	1	15.41		2002	1	13.42
1994	2	14.05		1998	2	12.32		2002	2	19.65
1994	3	13.26		1998	3	15.35		2002	3	15.63
1994	4	15.38		1998	4	13.68				
1994	5	15.33		1998	5	15.80				
1994	6	12.89		1998	6	14.35				
1994	7	10.03		1998	7	10.74				
1994	8	12.34		1998	8	11.26				
1994	9	9.26		1998	9	12.49				
1994	10	12.98		1998	10	16.29				
1994	11	16.34		1998	11	17.59				
1994	12	11.46		1998	12	15.67				
1995	1	13.70		1999	1	16.56				
1995	2	15.51		1999	2	16.07				
1995	3	15.72		1999	3	15.86				
1995	4	15.08		1999	4	16.38				
1995	5	12.12		1999	5	14.94				
1995	6	12.48		1999	6	12.52				
1995	7	11.52		1999	7	12.67				
1995	8	11.14		1999	8	11.59				
1995	9	12.45		1999	9	12.30				
1995	10	14.44		1999	10	13.73				
1995	11	12.81		1999	11	15.52				
1995	12	10.91		1999	12	12.84				
1996	1	12.11		2000	1	12.46				
1996	2	14.10		2000	2	14.65				
1996	3	15.44		2000	3	14.21				
1996	4	15.13		2000	4	15.17				
1996	5	13.24		2000	5	14.11				
1996	6	11.35		2000	6	12.67				
1996	7	12.14		2000	7	9.96				
1996	8	10.61		2000	8	11.92				
1996	9	11.73		2000	9	14.61				
1996	10	15.40		2000	10	13.75				
1996	11	13.14		2000	11	14.65				
1996	12	12.79		2000	12	17.21				
1997	1	13.98		2001	1	16.25				
1997	2	14.51		2001	2	14.21				
1997	3	15.22		2001	3	13.15				
1997	4	14.64		2001	4	15.77				
1997	5	15.93		2001	5	13.30				
1997	6	11.89		2001	6	11.85				
1997	7	10.91		2001	7	10.41				
1997	8	11.47		2001	8	12.72				
1997	9	13.85		2001	9	14.71				
1997	10	13.74		2001	10	15.79				
1997	11	13.15		2001	11	16.93				
1997	12	12.33		2001	12	12.05				

Appendix 2: Summarized Wind speed (km)

Mean annual and in summer, vs. winter seasons

Year	Annual	May-Aug	Apr. - Oct.	Nov. - Mar.
1970	18.38	18.51	20.94	18.66
1971	18.65	17.41	20.21	22.03
1972	20.51	19.64	23.42	20.24
1973	19.79	17.70	22.11	19.78
1974	18.30	18.45	21.45	18.50
1975	20.24	19.27	23.42	22.47
1976	20.28	18.47	22.72	19.84
1977	19.35	18.83	21.56	19.61
1978	18.22	18.94	21.02	16.89
1979	16.34	15.40	18.09	16.67
1980	15.60	13.81	17.14	17.36
1981	16.98	15.69	19.30	17.16
1982	15.73	14.00	17.92	15.92
1983	14.80	12.66	16.05	16.60
1984	14.64	12.60	15.71	16.58
1985	14.39	12.96	16.17	15.11
1986	14.49	13.30	16.55	13.64
1987	13.85	12.32	15.70	16.67
1988	16.06	14.34	17.66	15.94
1989	14.04	11.96	15.17	15.78
1990	14.23	12.19	14.95	14.18
1991	12.19	10.85	13.69	13.21
1992	12.23	11.00	13.20	14.09
1993	13.83	12.05	15.44	14.15
1994	13.16	12.65	14.49	14.54
1995	13.16	11.82	14.99	13.08
1996	13.10	11.84	15.01	13.93
1997	13.47	12.55	15.38	13.71
1998	14.25	13.04	15.71	16.35
1999	14.25	12.93	15.71	13.93
2000	13.78	12.16	15.20	15.09
2001	13.93	12.07	15.39	15.54
2002	14.79	12.98	16.25	

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2d: Long-term Hours of Bright Sunshine changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1972	11	52.7		1977	1	100.2		1981	1	102.0
1972	12	58.5		1977	2	78.3		1981	2	80.2
1973	1	98.8		1977	3	166.9		1981	3	107.4
1973	2	133.1		1977	4	240.3		1981	4	187.9
1973	3	113.6		1977	5	345.2		1981	5	237.6
1973	4	223.5		1977	6	244.1		1981	6	200.8
1973	5	194.2		1977	7	270.1		1981	7	326.6
1973	6	206.8		1977	8	201.6		1981	8	240.6
1973	7	283.0		1977	9	117.2		1981	9	126.3
1973	8	218.0		1977	10	163.1		1981	10	127.9
1973	9	172.0		1977	11	69.4		1981	11	104.6
1973	10	127.8		1977	12	60.8		1981	12	43.6
1973	11	80.6		1978	1	105.8		1982	1	113.5
1973	12	81.6		1978	2	150.6		1982	2	128.9
1974	1	98.5		1978	3	187.1		1982	3	148.1
1974	2	163.4		1978	4	214.8		1982	4	225.0
1974	3	183.6		1978	5	276.7		1982	5	222.1
1974	4	217.9		1978	6	270.6		1982	6	266.2
1974	5	186.5		1978	7	274.7		1982	7	297.1
1974	6	205.0		1978	8	283.6		1982	8	205.1
1974	7	213.0		1978	9	137.2		1982	9	123.2
1974	8	297.0		1978	10	113.3		1982	10	113.9
1974	9	139.8		1978	11	120.2		1982	11	73.7
1974	10	99.8		1978	12	78.3		1982	12	54.9
1974	11	78.9		1979	1	91.9		1983	1	57.8
1974	12	61.4		1979	2	159.8		1983	2	84.2
1975	1	71.5		1979	3	115.7		1983	3	120.9
1975	2	112.0		1979	4	171.4		1983	4	152.7
1975	3	186.4		1979	5	225.1		1983	5	188.6
1975	4	241.4		1979	6	264.6		1983	6	280.7
1975	5	271.7		1979	7	316.8		1983	7	295.5
1975	6	296.6		1979	8	219.7		1983	8	258.8
1975	7	314.6		1979	9	180.4		1983	9	161.4
1975	8	290.5		1979	10	82.6		1983	10	149.2
1975	9	138.8		1979	11	30.5		1983	11	66.8
1975	10	136.8		1979	12	80.2		1983	12	73.0
1975	11	72.3		1980	1	118.6		1984	1	98.6
1975	12	105.8		1980	2	157.1		1984	2	67.1
1976	1	116.6		1980	3	143.8		1984	3	184.0
1976	2	98.9		1980	4	142.3		1984	4	199.1
1976	3	120.0		1980	5	249.2		1984	5	167.7
1976	4	206.9		1980	6	181.5		1984	6	209.2
1976	5	229.1		1980	7	277.3		1984	7	270.6
1976	6	297.0		1980	8	213.9		1984	8	240.1
1976	7	284.8		1980	9	129.3		1984	9	143.7
1976	8	282.2		1980	10	119.7		1984	10	144.7
1976	9	193.3		1980	11	87.9		1984	11	83.1
1976	10	111.9		1980	12	123.9		1984	12	46.3
1976	11	81.5								
1976	12	85.0								

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2d cont'd : Long-term Hours of Bright Sunshine changes 1970 to 2001

Year	Month	Value		Year	Month	Value		Year	Month	Value
1985	1	82.4		1989	1	115.4		1993	1	93.1
1985	2	92.7		1989	2	148.0		1993	2	132.6
1985	3	171.6		1989	3	160.1		1993	3	172.9
1985	4	179.7		1989	4	184.7		1993	4	160.2
1985	5	256.1		1989	5	205.8		1993	5	175.8
1985	6	285.7		1989	6	178.7		1993	6	214.7
1985	7	307.4		1989	7	357.8		1993	7	279.9
1985	8	262.9		1989	8	207.5		1993	8	237.5
1985	9	160.1		1989	9	192.5		1993	9	153.5
1985	10	165.5		1989	10	126.7		1993	10	81.5
1985	11	73.4		1989	11	70.1		1993	11	64.0
1985	12	78.2		1989	12	103.0		1993	12	49.3
1986	1	89.1		1990	1	69.1		1994	1	106.5
1986	2	124.7		1990	2	133.3		1994	2	96.3
1986	3	102.1		1990	3	163.2		1994	3	144.4
1986	4	200.8		1990	4	172.7		1994	4	162.4
1986	5	203.1		1990	5	200.8		1994	5	264.8
1986	6	273.3		1990	6	200.2		1994	6	224.4
1986	7	240.1		1990	7	260.6		1994	7	222.3
1986	8	261.2		1990	8	235.9		1994	8	223.7
1986	9	118.3		1990	9	132.3		1994	9	156.3
1986	10	120.8		1990	10	101.9		1994	10	124.5
1986	11	81.4		1990	11	77.6		1994	11	92.6
1986	12	63.4		1990	12	66.9		1994	12	57.4
1987	1	92.4		1991	1	87.3		1995	1	73.3
1987	2	174.0		1991	2	131.1		1995	2	138.7
1987	3	178.9		1991	3	155.6		1995	3	161.7
1987	4	224.1		1991	4	174.1		1995	4	0.0
1987	5	241.5		1991	5	257.9		1995	5	222.3
1987	6	266.1		1991	6	288.9		1995	6	287.7
1987	7	272.3		1991	7	231.3		1995	7	249.8
1987	8	265.4		1991	8	260.1		1995	8	251.4
1987	9	151.7		1991	9	158.6		1995	9	154.6
1987	10	104.8		1991	10	102.5		1995	10	62.2
1987	11	64.4		1991	11	65.5		1995	11	78.5
1987	12	54.6		1991	12	85.1		1995	12	53.4
1988	1	99.7		1992	1	57.8		1996	1	98.9
1988	2	124.8		1992	2	109.8		1996	2	137.0
1988	3	146.3		1992	3	140.1		1996	3	169.6
1988	4	148.8		1992	4	168.9		1996	4	153.9
1988	5	267.2		1992	5	281.2		1996	5	260.4
1988	6	285.3		1992	6	247.3		1996	6	155.7
1988	7	300.5		1992	7	189.4		1996	7	233.7
1988	8	241.5		1992	8	178.4		1996	8	303.4
1988	9	0.0		1992	9	143.0		1996	9	154.8
1988	10	166.9		1992	10	113.9		1996	10	106.8
1988	11	43.8		1992	11	59.4		1996	11	77.1
1988	12	71.1		1992	12	42.0		1996	12	34.1

Appendix 2: Long-term changes in the meteorology in the Sudbury airport MET data

2d cont'd : Long-term Hours of Bright Sunshine changes 1970 to 2001

Year	Month	Value		Year	Month	Value
1997	1	60.5		2001	1	61.4
1997	2	105.8		2001	2	118.3
1997	3	192.3		2001	3	196.3
1997	4	227.0		2001	4	199.9
1997	5	199.0		2001	5	231.5
1997	6	309.8		2001	6	269.4
1997	7	292.4		2001	7	289.2
1997	8	213.5		2001	8	271.7
1997	9	163.8		2001	9	146.2
1997	10	122.4		2001	10	107.2
1997	11	77.6		2001	11	68.9
1997	12	76.8		2001	12	61.3
1998	1	59.5		2002	1	60.7
1998	2	99.3		2002	2	82.4
1998	3	144.5		2002	3	167.9
1998	4	263.6		2002	4	198.2
1998	5	278.9		2002	5	205.1
1998	6	218.7		2002	6	247.3
1998	7	301.0		2002	7	313.2
1998	8	228.7		2002	8	311.8
1998	9	192.0		2002	9	217.5
1998	10	150.4		2002	10	127.1
1998	11	38.1		2002	11	53.0
1998	12	99.5		2002	12	61.2
1999	1	88.8				
1999	2	131.1				
1999	3	226.6				
1999	4	253.3				
1999	5	287.2				
1999	6	272.3				
1999	7	275.1				
1999	8	276.6				
1999	9	226.8				
1999	10	135.3				
1999	11	72.6				
1999	12	59.6				
2000	1	106.4				
2000	2	126.1				
2000	3	156.6				
2000	4	218.8				
2000	5	222.9				
2000	6	202.9				
2000	7	250.9				
2000	8	219.8				
2000	9	182.6				
2000	10	160.2				
2000	11	50.7				
2000	12	62.2				

Appendix 2: Summarized Hours of Bright Sunshine
Total annual and in summer, vs. winter seasons

Year	Annual	May - Aug.	Apr. - Oct.	Nov. - Mar.
1973	1933.0	902.00	1425.30	607.70
1974	1944.8	901.50	1359.00	510.20
1975	2238.4	1173.40	1690.40	513.60
1976	2107.2	1093.10	1605.20	511.90
1977	2057.2	1061.00	1581.60	573.70
1978	2212.9	1105.60	1570.90	565.90
1979	1938.7	1026.20	1460.60	530.20
1980	1944.5	921.90	1313.20	501.40
1981	1885.5	1005.60	1447.70	538.70
1982	1971.7	990.50	1452.60	391.50
1983	1889.6	1023.60	1486.90	489.50
1984	1854.2	887.60	1375.10	476.10
1985	2115.7	1112.10	1617.40	467.50
1986	1878.3	977.70	1417.60	590.10
1987	2090.2	1045.30	1525.90	489.80
1988	1895.9	1094.50	1410.20	538.40
1989	2050.3	949.80	1453.70	538.70
1990	1814.5	897.50	1304.40	518.50
1991	1998.0	1038.20	1473.40	458.30
1992	1731.2	896.30	1322.10	500.00
1993	1815.0	907.90	1303.10	460.50
1994	1875.6	935.20	1378.40	523.70
1995	1733.6	1011.20	1228.00	537.40
1996	1885.4	953.20	1368.70	469.80
1997	2040.9	1014.70	1527.90	457.70
1998	2074.2	1027.30	1633.30	584.10
1999	2305.3	1111.20	1726.60	521.30
2000	1960.1	896.50	1458.10	488.90
2001	2021.3	1061.80	1515.10	441.20
2002	2045.4	1077.40	1620.20	